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by Staff of the Engineering and Terrain Geology Section, Ontario Geological Survey

1988

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Aggregate Resources Inventory of Sunnidale Township Simcoe County

by
Staff[1] of the Engineering and Terrain Geology Section

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Abstract

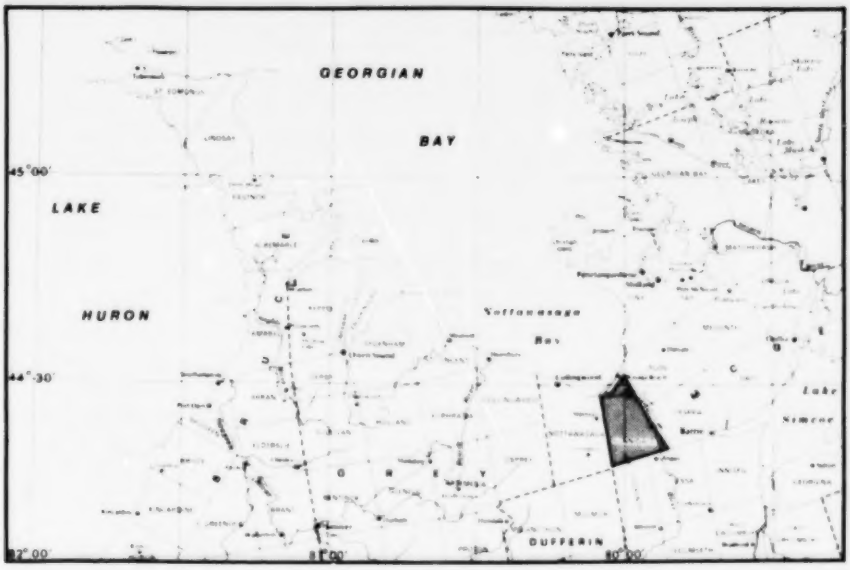


Figure 1. Key Map Showing the Location of Sunnidale Township, Scale 1:1 800 000.

This report includes both an inventory and evaluation of sand and gravel, as well as bedrock resources, in Sunnidale Township. The report is part of the Aggregate Resources Inventory Program for townships and municipalities designated under the Pits and Quarries Control Act.

In Sunnidale Township, three areas containing sand and gravel have been selected as Resource Areas of Primary Significance. Selected Resource Areas 1 and 2 consist of glaciolacustrine beach deposits related to the abandoned shorelines of glacial Lake Algonquin. Both of these Areas have been regional sources of road-building and construction materials for many years and currently have an estimated 8 million tons (7 million tonnes) of sand and gravel available for extraction.

Deposits of glaciofluvial outwash gravel associated with the Creemore channel deposit constitute Selected Resource Area 3. This resource area contains possible resources of approximately 1 million tons (1 million tonnes) of sand and gravel. The parts of the selected areas which are available for extraction represent only about 2 percent of the total area occupied by sand and gravel deposits in the township and 1 percent of the original resource tonnage.

In addition to these deposits, two beach deposits related to glacial Lake Nipissing have been selected as Resource Areas of Secondary Significance. Although these deposits are not the most important resources in the township, they should be considered as part of the total aggregate supply.

Sunnidale Township is underlain by bedrock of the Verulam, Lindsay and Blue Mountain Formations of Middle and Upper Ordovician age. These formations have not been selected for possible resource protection because of the great thickness of overlying glacial sediments.

Selected Resource Areas are not intended to be permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

Introduction

Mineral aggregates, which include bedrock-derived crushed stone as well as naturally formed sand and gravel, constitute the major raw material in Ontario's road-building and construction industries. Very large amounts of these materials are used each year throughout the Province. For example, in 1984, the total tonnage of mineral aggregates extracted was 109 million tons (99 million tonnes), greater than that of any other metallic or nonmetallic commodity mined in the Province (Weatherson 1986).

Although mineral aggregate deposits are plentiful in Ontario, they are fixed-location, nonrenewable resources which can be exploited only in those areas where they occur. Mineral aggregates are characterized by their high bulk and low unit value so that the economic value of a deposit is a function of its proximity to a market area as well as its quality and size. The potential for extractive development is usually greatest in urban fringe areas where land use competition is extreme. For these reasons the availability of adequate resources for future development is now being threatened in some areas.

Comprehensive planning and resource management strategies are required to make the best use of available resources, especially in those areas experiencing rapid development. Such strategies must be based on a sound knowledge of the total mineral aggregate resource base at both local and regional levels. The purpose of the Aggregate Resources Inventory is to provide the basic geological information required to include potential mineral aggregate resource areas in planning strategies and official plans. The reports should form the basis for discussion on those areas best suited for possible extraction. The aim is to assist decision-makers in protecting the public well-being by ensuring that adequate resources of mineral aggregate remain available for future use.

This report is a technical background document, based for the most part on geological information and interpretation. It has been designed as a component of the total planning process and should be used in conjunction with other planning considerations, to ensure the best use of a municipality's resources.

The report includes an assessment of sand and gravel resources as well as a discussion on the potential of bedrock-derived aggregate. The most recent information available has been used to prepare the report. As new information becomes available, revisions may be necessary.

Part I — Inventory Methods

FIELD AND OFFICE METHODS

The methods used to prepare the report primarily involve the interpretation of published geological data such as bedrock and surficial geology maps and reports (see References) as well as field examination of potential resource areas. Field methods include the examination of natural and man-made exposures of granular material. Most observations are made at quarries and sand and gravel pits located from records held by the Ontario Ministry of Transportation, the Ontario Geological Survey, and by Regional and District Offices of the Ontario Ministry of Natural Resources. Observations made at pit sites include estimates of the total face height and the proportion of gravel- and sand-sized fragments in the deposit. Observations are also made of the shape and lithology of the particles. These characteristics are important in estimating the quality and quantity of the aggregate. In areas of limited exposure, subsurface materials may be assessed by hand augering and test pitting, supplemented by test hole drilling, and geophysical surveys using hammer seismic equipment. The symbols for and locations of sample sites, test hole sites, and geophysical traverse lines are noted on Map 1.

Deposits with potential for further extractive development or those where existing data are scarce, are studied in greater detail. Representative layers in these deposits are sampled in 25- to 100-pound (11- to 45-kg) units from existing pit faces or from test pits. The samples are analysed for grain size distribution, and in some cases absorption, Los Angeles abrasion, and Magnesium Sulphate soundness tests and petrographic analyses are carried out. Analyses are performed either in the laboratories of the Soils and Aggregates Section, Engineering Materials Office, Ontario Ministry of Transportation, or in the Geoscience Laboratories, Geoservices Section, Ontario Geological Survey.

The field data are supplemented by pit information on file with the Soils and Aggregates Section of the Ontario Ministry of Transportation. Data contained in these files include field estimates of the depth, composition, and "workability" of deposits, as well as laboratory analyses of the physical properties and chemical suitability of the aggregate. Information concerning the development history of the pits and acceptable uses of the aggregate is also recorded. The location, size, and depth of extraction of pits licenced under the Pits and Quarries Control Act are obtained from records held by Regional and District Offices of the Ontario Ministry of Natural Resources. The cooperation of the above-named groups in the compilation of inventory data is gratefully acknowledged.

Aerial photographs at various scales are used to determine the continuity of deposits, especially in areas where information is limited. Water well records, held by the Ontario Ministry of the Environment, are used in some areas to corroborate deposit thickness estimates or to indicate the presence of buried granular material. These records are used in conjunction with other evidence.

Topographic maps of the National Topographic System, at a scale of 1:50 000, are used as a compilation base for the field and office data. The information is then transferred to a base map, also at a scale of 1:50 000, prepared by the Cartography Section of the Lands and Waters Group, Ontario Ministry of Natural Resources, for presentation in the report.

RESOURCE TONNAGE CALCULATION TECHNIQUES

SAND AND GRAVEL RESOURCES

Once the interpretative boundaries of the aggregate units have been established, quantitative estimates of the possible resources available can be made. Generally, the volume of a deposit can be calculated if its areal extent and average thickness are known or can be estimated. The computation methods used are as follows. First, the area of the deposit, as outlined on the final base map, is calculated in acres. The thickness values used are an approximation of the deposit thickness, based on the face heights of pits developed in the deposit or on subsurface data such as test holes and water well logs. Original tonnage values can then be calculated by multiplying the volume of the deposit by 2500 (the density factor). This factor is approximately the number of tons in a one-foot (0.3 m) thick layer of sand and gravel, one acre (0.4 ha) extent, assuming an average density of 110 pounds per cubic foot (1766 kg per cubic metre).

Tonnage = Area x Thickness x Density Factor

Tonnage calculated in this manner must be considered only as an estimate. Furthermore, such tonnages represent amounts that existed prior to any extraction of material (i.e. original tonnage) (Table 1, Column 4).

The Selected Sand and Gravel Resource Areas in Table 3 are calculated in the following way. Two successive subtractions are made from the total area. Column 3 accounts for the number of acres unavailable because of the presence of permanent cultural features and their associated setback requirements. Column 4 accounts for those areas that have previously been extracted (e.g. wayside and abandoned pits are included in this category). The remaining figure is the area of the deposit currently available for extraction (Column 5). The available area is then multiplied by the estimated deposit thickness and the density factor (Column 5 x Column 6 x 2500) to give an estimate of the sand and gravel tonnage (Column 7) presently available for extractive development and/or resource protection.

Reserve estimates are calculated for deposits of primary significance. Reserve estimates for deposits of secondary and tertiary significance are not calculated in Table 3, however the aggregate potential of these deposits is discussed in the report.

BEDROCK RESOURCES

The method used to calculate resources of bedrock-derived aggregate is much the same as that described above. The areal extent of bedrock formations overlain by less than 50 feet (15 m) of unconsolidated overburden is determined from bedrock geology maps, drift thickness and bedrock topography

maps, and from the interpretation of water well records. The measured extent of such areas is then multiplied by the estimated quarriable thickness of the formation, based on stratigraphic analyses and on estimates of existing quarry faces in the unit. In some cases a standardized estimate of 60 feet (18 m) is used for thickness. Volume estimates are then multiplied by the density factor (the estimated weight in tons of a one-foot (0.3 m) thick section of rock, one acre (0.4 ha) in extent).

Resources of dolostone are calculated using a density factor of 165 pounds per cubic foot (2649 kg per cubic metre) or 3600 tons per acre (8070 tonnes per hectare). Sandstone resources are calculated using a density estimate of 146 pounds per cubic foot (2344 kg per cubic metre) and shale resources are calculated with a factor of 150 pounds per cubic foot (2408 kg per cubic metre).

UNITS AND DEFINITIONS

Although most of the measurements and other primary data available for resource tonnage calculations are given in Imperial units, Metric units have also been given in the text and on the tables which accompany the report. The Metric equivalent of the data is shown in brackets after or directly below the corresponding Imperial figures. Data are generally rounded off in accordance with the Ontario Metric Practice Guide (Metric Committee 1975).

The tonnage estimates made for sand and gravel deposits are termed possible resources (see Glossary, Appendix B) in accordance with terminology of the Ontario Resource Classification Scheme (Robertson 1975, p.7) and with the Association of Professional Engineers of Ontario (1976).

Part II — Data Presentation and Interpretation

Three maps, each portraying a different aspect of the aggregate resources in the municipality, accompany the report. Map 1, "Distribution of Sand and Gravel Deposits", gives a comprehensive inventory of the sand and gravel resources in the report area. Map 2, "Selected Sand and Gravel Resource Areas", shows those deposits which are considered to represent the largest and/or highest quality resources in the area. Map 3, "Bedrock Resources" shows the distribution of bedrock formations, the thickness of overlying unconsolidated sediments, and identifies the Selected Bedrock Resource Areas.

MAP 1: DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

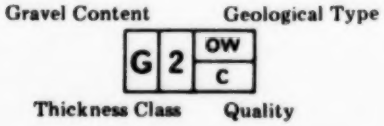
Map 1 is derived from existing surficial geology maps of the area or from aerial photograph interpretation in areas where surficial mapping is incomplete. The map shows the extent and quality of sand and gravel deposits within the study area and the present level of extractive activity.

On the map, gravel deposits are indicated by dark brown shading while sand deposits are shaded light brown. The present level of extractive activity is also indicated. Those areas which are licenced for extraction under the Pits and Quarries Control Act are shown by a solid outline and identified by a number which refers to the pit descriptions in Table 2. Each description notes the owner/operator, location and licenced acreage of the pit, as well as the estimated face height and percentage gravel. A number of unlicenced pits (abandoned pits or wayside pits operating on demand under authority of a permit) are identified by a numbered dot on Map 1 and described in Table 2. Similarly, test hole locations appear on Map 1 as a point symbol and are described in Table 7. Geophysics lines are shown on Map 1 by a line symbol and are interpreted in Table 8.

Map 1 also presents a summary of available information related to the quality of aggregate contained in all the known aggregate deposits in the study area. Much of this information is contained in the symbols which are found on the map. The Deposit Symbol appears for each mapped deposit and summarizes important genetic and textural data. The Texture Symbol is a circular proportional diagram which displays the grain size distribution of the aggregate in areas where bulk samples were taken.

DEPOSIT SYMBOL

The Deposit Symbol is similar to those used in soil mapping and land classification systems commonly in use in North America. The components of the symbol indicate the gravel content, thickness of material, origin (type), and quality limitations for every deposit shown on Map 1. These components are illustated by the following example:



This symbol identifies an outwash deposit 10 to 20 feet (3 to 6 m) thick containing more than 35 percent gravel. Excess silt and clay may limit uses of the aggregate in the deposit.

The "gravel content" and "thickness class" are basic criteria for distinguishing different deposits. The "gravel content" symbol is an upper case "S" or "G". The "S" indicates that the deposit is generally "sandy" and that gravel-sized aggregate (greater than 4.75 mm) makes up less than 35 percent of the whole deposit. "G" indicates that the deposit contains more than 35 percent gravel.

The "thickness class" indicates a depth range which is related to the potential resource tonnage for each deposit. Four thickness class divisions have been established as shown in the legend for Map 1.

Two smaller sets of letters, divided from each other by a horizontal line, follow the thickness class number. The upper series of letters identifies the geologic deposit type (the deposit types are summarized with respect to their main geologic and extractive characteristics in Appendix C) and the lower series of letters identifies the main quality limitations that may be present in the deposit as discussed in the next section.

TEXTURE SYMBOL

The Texture Symbol provides a more detailed assessment of the grain size distribution of material sampled during field study. These symbols are derived from the information plotted on the aggregate grading curves found in the report. The relative amounts of gravel, sand, and silt and clay in the sampled material are shown graphically in the Texture Symbol by the subdivision of a circle into proportional segments. The following example shows a hypothetical sample consisting of 30 percent gravel, 60 percent sand, and 10 percent silt and clay:

MAP 2: SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 2 is an interpretative map derived from an evaluation of the deposits shown on Map 1. The deposits identified on Map 2 are those which are considered to be important in ensuring an adequate resource base for the future.

All the selected sand and gravel resource areas are first delineated by geological boundaries and then classified into three levels of significance: primary; secondary; and tertiary. Each area of primary significance is assessed as to its probable relative value as a resource in the municipality and is given a deposit number which denotes its ranking order. All such deposits are shown by dark red shading on Map 2.

Deposits of secondary significance are not ranked numerically in this report, but are indicated by light red shading on Map 2. Such deposits are believed to contain significant amounts of sand and gravel. Although deposits of secondary significance are not considered to be the "best" resources in the report area, they may contain large quanitities of sand and gravel and should be considered as part of the aggregate supply of the area.

Areas of tertiary significance are outlined on the map by a solid line but have no shading. They are not considered to be important resource areas because of their low available resources, or because of possible difficulties in extraction. Such areas may be useful for local needs but are unlikely to support large-scale development.

Selected Sand and Gravel Resource Areas of primary significance are not permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

The process by which deposits are evaluated and selected involves the consideration of two sets of criteria. The main selection criteria are site specific, related to the characteristics of individual deposits. Factors such as deposit size, aggregate quality, and deposit location and setting are considered in the selection of those deposits best suited for extractive development. A second set of criteria involves the assessment of local aggregate resources in relation to the quality, quantity, and distribution of resources in the region in which the report area is located. The intent of such a process of evaluation is to ensure the continuing availability of sufficient resources to meet possible future demands.

SITE SPECIFIC CRITERIA

Deposit Size

Ideally, selected deposits should contain available sand and gravel resources large enough to support a commercial pit operation using a stationary or portable processing plant. In practice, much smaller deposits may be of significant value depending on the overall reserves in the rest of the municipality. Generally, deposits in Class 1 (greater than 20 feet (6 m) thick), and containing more than 35 percent gravel are considered to be most favourable for commercial development. Thinner deposits may be valuable in municipalities with low total resources.

Aggregate Quality

The limitations of natural aggregates for various uses result from variations in the lithology of the particles composing the deposit, and from variations in the size distribution of these particles.

Four indicators of the quality of aggregate may be included in the deposit symbols on Map 1. They are: gravel content (G or S); fines (C); oversize (O); and lithology (L).

Three of the quality indicators deal with grain size distribution. The gravel content (G or S) indicates the suitability of aggregate for various uses. Deposits containing at least 35 percent gravel in addition to a minimum of 20 percent material greater than the 26.5 mm sieve are considered to be the most favourable extractive sites, since this content is the minimum from which crushed products can be economically produced.

Excess fines (high silt and clay content) may severely limit the potential use of a deposit. Fines content in excess of 10 percent may impede drainage in road sub-base aggregate and render it more susceptible to the effects of frost action. In asphalt aggregate, excess fines hinder the bonding of particles. Deposits known to have a high fines content are indicated by a "C" in the quality portion of the Deposit Symbol.

Deposits containing more than 20 percent oversize material (greater than 4 inches (10 cm) in diameter) may also have use limitations. The oversize component is unacceptable for all concrete aggregate and for road-building aggregate, so it must be either crushed or removed during processing. Deposits known to have an appreciable oversize component are indicated by an "O" in the quality portion of the Deposit Symbol.

Another indicator of the quality of an aggregate is lithology. Just as the unique physical and chemical properties of bedrock types determine their value for use as crushed rock, so do various lithologies of particles in a sand and gravel deposit determine its suitability for various uses. The presence of objectionable lithologies such as chert, siltstone, and shale, even in relatively small amounts, can result in a reduction in the quality of an aggregate, especially for high quality uses such as concrete and asphalt. Similarly, highly weathered, very porous and friable rock can restrict the quality of an aggregate. Deposits known to contain objectionable lithologies are indicated by an "L" in the quality component of the Deposit Symbol.

If the Deposit Symbol shows either "C", "O", or "L" or any combination of these indicators, the quality of the deposit is considered to be reduced for some uses of the aggregate. No attempt is made to quantify the degree of limitation imposed. Assessment of the four indicators is made from published data, from data contained in files of both the Ontario Ministry of Transportation and the Engineering and Terrain Geology Section of the Ontario Geological Survey, and from field observations.

Quality data may also appear in Table 9, where the results of aggregate quality tests are listed by test type and sample location. The types of tests conducted and the test specifications are explained in Appendices B and E, respectively.

Analyses of unprocessed samples obtained from test holes, pits or sample sites are plotted on grain size distribution graphs. On the graphs are the Ontario Ministry of Transportation's gradation specification envelopes for aggregate products: Granular Base Course A, B and C; Hot-Laid Asphaltic Sand Nos. 1,2,3,4, and 8; and concrete sand. By plotting the gradation curves with respect to the specification

envelopes, it can be determined how well the unprocessed sampled material meets the criteria for each product. These graphs, called Aggregate Grading Curves, follow the tables in the report.

Location and Setting

The location and setting of a resource area has a direct influence on its value for possible extraction. The evaluation of a deposit's setting is made on the basis of natural and man-made features which may limit or prohibit extractive development.

First, the physical context of the deposit is considered. Deposits with some physical constraint on extractive development, such as thick overburden or high water table, are less valuable resource areas because of the difficulties involved in resource recovery. Second, permanent man-made features, such as roads, railways, powerlines, and housing developments, which are built on a deposit, may prohibit its extraction. The constraining effect of legally required setbacks surrounding such features is included in the evaluation. A quantitative assessment of these constraints can be made by measurement of their areal extent directly from the topographic maps. The area rendered unavailable by these features is shown for each resource area in Table 3 (Column 3).

The assessment of sand and gravel deposits with respect to local land use and to private land ownership is an important component of the general evaluation process. These aspects of the evaluation process are not considered further in this report, but readers are encouraged to discuss them with personnel of the pertinent District Office of the Ontario Ministry of Natural Resources.

REGIONAL CONSIDERATIONS

In selecting sufficient areas for resource development, it is important to assess both the local and the regional resource base, and to forecast future production and demand patterns.

Some appreciation of future aggregate requirements in an area may be gained by assessing its present production levels and by forecasting future production trends. Such an approach is based on the assumptions that production levels in an area closely reflect the demand and that the present production "market share" of an area will remain roughly at the same level.

The aggregate resources in the region surrounding a municipality should be assessed in order to properly evaluate specific resource areas and to adopt optimum resource management plans. For example, a municipality that has large resources in comparison to its surrounding region constitutes a regionally significant resource area. Municipalites with high resources in proximity to large demand centres, such as metropolitan areas, are special cases.

Although an appreciation of the regional context is required to develop comprehensive resource management techniques, such detailed evaluation is beyond the scope of this report. The selection of resource areas made in this study is based primarily on geological data or on considerations outlined in preceding sections.

MAP 3: BEDROCK RESOURCES

Map 3 is an interpretative map derived from bedrock geology, drift thickness and bedrock topography maps, water well data from the Ontario Ministry of the Environment, oil and gas well data from the Petroleum Resources Section (Ontario Ministry of Natural Resources) and from geotechnical test hole data from various sources. Map 3 is based on concepts similar to those outlined for Maps 1 and 2, but displays both the inventory and evaluation on the one map.

The geological boundaries of the bedrock units are shown by a dashed line. Isolated outcrops are indicated by an "X". Three sets of contour lines delineate areas of less than 3 feet (1 m) of drift, areas of 3 to 25 feet (1 to 8 m) of drift, and areas of 25 to 50 feet (8 to 15 m) of drift. The extent of these areas of thin drift are shown by three shades of blue. The darkest shade indicates where bedrock outcrops or is within 3 feet (1 m) of the ground surface. These areas consitute potential resource areas because of their easy access. The medium shade indicates areas where drift cover is up to 25 feet (8 m) thick. Quarrying is possible in this depth of overburden and these zones also represent potential resource areas. The lightest shade indicates bedrock areas overlain by 25 to 50 feet (8 to 15 m) of overburden. These latter areas constitute resources which have extractive value only in specific circumstances. Outside of these delineated areas, the bedrock can be assumed to be covered by more than 50 feet (15 m) of overburden, a depth generally considered to be too great to allow economic extraction (unless part of the overburden is composed of economically attractive deposits).

Other inventory information presented on Map 3 is designed to give an indication of the present level of extractive activity in the report area. Those areas which are licenced for extraction under the Pits and Quarries Control Act are shown by a solid outline and identified by a number which refers to the quarry descriptions in Table 5. Each description notes the owner/operator, location, licenced acreage and an estimate of face height. Unlicenced quarries (abandoned quarries or wayside quarries operating on demand under authority of a permit) are also identified and numbered on Map 3 and described in Table 5. Two additional symbols may appear on the map. An open dot indicates the location of a selected water well which penetrates bedrock. The overburden thickness is shown in feet beside the open dot. Similarly, test hole locations appear as a point symbol with the depth to bedrock shown in feet beside it. The test holes may be further described in Table 7.

SELECTION CRITERIA

Criteria equivalent to those used for sand and gravel deposits are used to select bedrock areas most favourable for extractive development.

The evaluation of bedrock resources is made primarily on the basis of performance and suitability data established by laboratory testing at the Ontario

Ministry of Transportation. The main characteristics and uses of the bedrock units found in southern Ontario are summarized in Appendix D.

Deposit "size" is related directly to the areal extent of thin drift cover overlying favourable bedrock formations. Since vertical and lateral variations in bedrock units are much more gradual than in sand and gravel deposits, the quality and quantity of the resource are usually consistent over large areas.

Quality of the aggregate derived from specific bedrock units is established by the performance standards previously mentioned. Location and setting criteria and regional considerations are identical to those for sand and gravel deposits.

SELECTED RESOURCE AREAS

Selection of Bedrock Resource Areas has been restricted to a single level of significance. Three factors support this approach. First, quality and quantity variations are gradual. Second, the areal extent of a given quarry operation is much smaller than that of a sand and gravel pit producing an equivalent tonnage of material, and third, since crushed bedrock has a higher unit value than sand and gravel, longer haul distances can be considered. These factors allow the identification of alternative sites having similar development potential. The Selected Areas, if present, are shown on Map 3 by a line pattern and the calculated available tonnages are given in Table 6.

Selected Bedrock Resource Areas shown on Map 3 are not permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major bedrock resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

Part III - Assessment of Aggregate Resources in Sunnidale Township

LOCATION AND POPULATION

Sunnidale Township occupies an area of 49,553 acres (20 054 ha) in central Simcoe County (Ontario Ministry of Municipal Affairs 1987). The township is shown at a scale of 1:50 000 on portions of the Collingwood (41 A/8), Nottawasaga (41 A/9), Orr Lake (31 D/12) and Barrie (31 D/5) map sheets of the National Topographic System.

The population of Sunnidale Township, exclusive of the town of Wasaga Beach, was 2309 in 1985 (Ontario Ministry of Municipal Affairs 1987). The majority of the residents are rural-farm or rural-residential inhabitants. Although the population has fluctuated, the township experienced less than a one percent increase in population between 1972 and 1985 (Ontario Ministry of Municipal Affairs 1987; Ontario Ministry of Treasury, Economics and Intergovernmental Affairs 1974).

The town of Wasaga Beach, located north of King's Highway 26, is the main regional trade and retail centre. The town's population increased 155 percent between 1972 and 1985, to reach 4588 (Ontario Ministry of Municipal Affairs 1987; Ontario Ministry of Treasury, Economics and Intergovernmental Affairs 1974). Much of this increase can be attributed to the town's scenic and recreational value as Wasaga Beach Provincial Park has consistently attracted a seasonal influx of recreational inhabitants and rural residents. Such population growth can only necessitate the increased production of mineral aggregates to satisfy construction needs. Other communities in the township include Sunnidale, Sunnidale Corners, New Lowell and Brentwood.

Road access to sand and gravel deposits within the township is provided by a grid of paved regional roads and gravel-surfaced township roads. King's Highways 26, 90, and 92 are also located in the area and serve as the main haulage routes to market centres. A line of the Canadian National Railways serves the south-central part of the township.

PHYSIOGRAPHY AND SURFICIAL GEOLOGY

The physiography of Sunnidale Township falls within the Simcoe Lowlands and Simcoe Uplands physiographic regions as described by Chapman and Putnam (1984). The uplands are associated with the Corn Hill Moraine (which exhibits classical morainic topography), the Lake Algonquin beach sediments, and an extensive complex of eolian dunes located in the town of Wasaga Beach. The lowlands constitute most of the study area and are mainly associated with large plains of lacustrine sand located in the southern part of the township.

Approximately 23 000 to 10 000 years ago, during the Great Ice Age (Late Wisconsinan Substage of the Pleistocene Epoch), lobes or submasses of the Laurentide Ice Sheet advanced out of the Great Lakes basins and joined together to entirely cover southern Ontario. The physiography and distribution of surficial materials in southern Ontario are largely the result of the repeated advance and melting back of the margins of these ice lobes. Within Sunnidale Township the southward and southwestward flowing Georgian Bay-Lake Simcoe ice lobes (Gwyn 1972) deposited predominantly glaciolacustrine, fluviolacustrine delta and outwash materials, as well as three separate till units.

An advance of the Georgian Bay lobe from the northwest laid down the oldest till in the township, informally named Allenwood till (Burwasser, in preparation). This material is a sandy silt till, partly modified by lacustrine action (Burwasser 1974d; Burwasser and Cairns 1974). This till is frequently exposed along the southern slope of the slightly hummocky Edenvale Moraine which is located between Sunnidale Corners and Phelpston (Flos Township, Simcoe County). The moraine exhibits glacial flutings that are parallel to the direction of ice movement (Burwasser, in preparation).

The next youngest till found in the township is the Newmarket Till (Gwyn 1972). This unit was deposited by the lobe advancing out of the Lake Simcoe basin from the northeast. The material is described as a light yellowish-brown, sand to compact silty sand till (Burwasser 1974a). The Corn Hill Moraine, located west of the hamlet of Sunnidale, is composed of Newmarket Till and represents the highest elevation in the township.

During the initial melting of the ice, intertill sediments were deposited. These sediments include the glaciofluvial outwash sand and gravel deposited south of the Corn Hill Moraine, and are associated with the Creemore outwash channel. Here, the outwash gravel has been modified by subsequent aqueous erosion and is masked by a thin veneer of older alluvium (Burwasser 1974a).

The youngest till was laid down by a re-advance of the Georgian Bay-Lake Simcoe Lobe. The till consists of highly contorted laminated silty clay (originally of glaciolacustrine origin) which contains grits and clay pebbles (Burwasser, in preparation). This unit has been referred to by Gwyn (1972) as Kettleby Till. The northern face of the Edenvale Moraine is composed of this till unit.

The three till units that occur in the township generally possess very little value as aggregate sources.

With the final retreat of the ice margin northward, approximately 12 000 to 12 500 years ago (Deane 1950; Lewis 1969), the waters of glacial Lake Algonquin inundated the lowland areas in the township. It was at this time, before isostatic rebound, that the lake level reached its maximum elevation.

The prolonged glaciolacustrine environment created the present-day flat to gently rolling lowland plain. This lake plain consists largely of silty fine-grained sand (Pit No. 13; Figure 4a). The sand appears to have been deposited as a body of outwash with some later reworking by the shallow waters of glacial Lake Algonquin (Burwasser, in preparation, 1974d). The fine-grained silts and sands are unsuitable for use as aggregate.

The 750-foot (229 m) elevation marks the main shorebluff of Lake Algonquin. The beach and near-

shore deposits at this elevation are the best sources of sand and gravel in the township. In particular, the large beach deposit located west of New Lowell is a major aggregate resource area for the township. The material in this deposit is well rounded, fine to medium gravel with interstratified medium to coarse sand. This material can be utilized for a wide range of road-building and general construction products.

A large area of estuarine delta sand and associated dunes breach the Algonquin bluff west of Brentwood. The probability of locating coarse aggregate in this deposit is quite low.

As the ice margin melted back to the north, the Fossmill outlet opened and the level of Lake Algonquin dropped to an all time low (Chapman and Putnam 1984; Burwasser, in preparation). As the ice continued to melt, a strong rebound of the land surface was occurring. During this time glacial Lake Nipissing was formed (Lewis 1970; Prest 1970). The Lake Nipissing shorebluff extends approximately parallel to the present shore of Nottawasaga Bay near the southern boundary of the town of Wasaga Beach. Aggregate from the Nipissing beach deposits has been used locally for a number of construction purposes.

Approximately 7000 years ago, the Nipissing coastal barrier island complex started to form (Martini 1974, 1975). This former barrier island complex can now be identified in the town of Wasaga Beach and consists of the barrier itself, the lagoon, and the eolian dunes that cap the main barrier. The lower part of the barrier consists of Nipissing sandy-gravelly beaches. These deposits have been used for a range of road-building and construction products. The lagoon or bay environment is located behind the barrier along the Nottawasaga River and is made up of peat, marl and sand (Martini 1975).

Postglacial and erosional processes have been of some importance in changing the land surface in the report area. The prominent dune complex in the town of Wasaga Beach is only partially stabilized and shows considerable evidence of remobilization. Organic detritus, peat and muck have also accumulated in the flat-lying basins associated with Jack Lake and the Minesing Swamp.

EXTRACTIVE ACTIVITY

Numerous sand and gravel pits have been opened in the township. Many of these pits have been developed in the glacial Lake Algonquin shoreline deposits. Other pits have also been opened in glaciofluvial outwash and glaciolacustrine sands. Data from the Ontario Ministry of Transportation suggest that the Lake Algonquin deposits are capable of producing high-quality coarse granular material acceptable for many road-building and construction purposes. Most of the sources developed in the large deposit located west of the hamlet of New Lowell are able to supply materials for Granular Base Course (G.B.C.) A and other lower grade requirements.

Many of the pits became inactive in 1973 when Sunnidale Township was designated under the Pits and Quarries Control Act. At the time of writing, records on file with the Huronia District Office of the Ontario Ministry of Natural Resources indicate that six licenced sand and gravel pits are located in the township. The total area licenced for extraction in the six pits is 478.9 acres (193.8 ha). Although they are not shown on Maps 1 and 2, two licenced pits also are to be found in the town of Wasaga Beach.

Since the year of designation, records of the total annual production from all licenced sources in the township and town of Wasaga Beach have been maintained by the Huronia District Office. The average annual production over the eight-year period from 1975 to 1982 is estimated to have been 270,000 tons (245 000 tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 1 illustrates the distribution of sand and gravel deposits in Sunnidale Township. The total area occupied by these deposits is approximately 16,800 acres (6800 ha), or 34 percent of the total area of the township. The deposits contain possible resources of 630 million tons (570 million tonnes). However, many of the fine-grained deposits included in the estimate have a low potential for use as road-building or construction aggregate.

The sand and gravel deposits selected for possible resource protection are indicated on Map 2. The Primary Resource Areas include glaciolacustrine beach deposits and glaciofluvial outwash gravel deposits which are potential sources of good-quality coarse aggregate. The Selected Areas of Primary Significance have a total area of 500 acres (202 ha), exclusive of licenced properties. The total available sand and gravel resources are estimated to be 9 million tons (8 million tonnes). The parts of the resource areas which are available for extraction represent only about 2 percent of the total area of sand and gravel deposits in the township and 1 percent of the original tonnage.

Two glaciolacustrine beach deposits have been selected at the secondary level of significance. There is a history of small-scale extraction associated with the larger of these deposits. Although these deposits are not the township's best aggregate sources, they should be considered to be part of the total aggregate supply.

SELECTED SAND AND GRAVEL RESOURCE AREA 1

Selected Sand and Gravel Resource Area 1 consists of an extensive glaciolacustrine beach deposit related to the abandoned shoreline of glacial Lake Algonquin. A very pronounced abandoned Algonquin shorebluff marks the erosional edge of the Corn Hill Moraine on the northern boundary of the Area.

Area 1 is the largest and best quality sand and gravel deposit in the township. There has been substantial aggregate extaction from this source over the past years. Consequently, much of the material has been depleted and sand tends to be the dominant sediment encountered in the deposit. Presently, four licenced properties (pit nos. 1, 2, 3 and 4) and two unlicenced pits (pit nos. 18 and 19) are found within the Area.

The licenced properties have faces ranging in height from 5 to 15 feet (1.5 to 5 m) and expose variable gravel contents ranging from 10 to 50 percent. Faces in these properties generally expose well rounded and well sorted fine to medium gravel with interstratified medium to coarse sand. Faces in the eastern part of pit no. 3 reveal a coarsening-upward sequence of open-work, well rounded crushable gravel with interstratified clean coarse sand. A sample from the eastern part of pit no. 3 revealed 48 percent gravel (Figure 2a).

Aggregate suitability data obtained from the Ministry of Transportation and from pit operators in the licenced properties indicate that this deposit has been and still is capable of supplying high-quality aggregate acceptable for a wide range of road-building and general construction products if suitable processing and quality control techniques are employed. Pit nos. 3, 4, 18 and 19 have been approved for supplying large quantities of G.B.C. A, B and C, 16 mm Crushed Types A and B, as well as Hot-Laid (H.L.) No. 4 asphaltic aggregate. Processing is required to crush or remove oversize material for the production of G.B.C. B and C. Most high-specification fine aggregate products are produced, provided suitable blending is employed to alter the grain size distribution of the coarser sands found in most properties. Finer sand can be blended with the coarser sand fraction to alter its gradation to meet the specifications of the desired product. The western part of licenced pit no. 3 is the processing area for all of the Martin properties in the township. A crushing, screening and washing plant produces a full line of stone and sand products, and in 1983 brick sand was produced for a substantial market.

Resource Area 1 occupies 200 acres (81 ha), exclusive of the licenced properties. Cultural constraints and previous extraction reduce the area presently available to 90 acres (36 ha). Based on pit face heights, the average thickness of usable material is estimated to be 15 feet (5 m). Therefore, the sand and gravel resources total approximately 3 million tons (3 million tonnes). Access to Area 1 is provided by County Road 9 which crosses the deposit.

SELECTED SAND AND GRAVEL RESOURCE AREAS 2a AND 2b

Selected Sand and Gravel Resource Areas 2a and 2b constitute all of the remaining glacial Lake Algonquin beach deposits in the township. Area 2a has been extensively worked in the past. There are presently two licenced properties (pit nos. 5 and 6) operating in the deposit. Three unlicenced pits have also operated in this Area (pit nos. 21, 22 and 23). Faces in the pits range in height from 5 to 25 feet (1.5 to 8 m) and expose gravel contents ranging between 20 and 35 percent. Faces in most sources are now overgrown, although in places they expose stratified fine to coarse sand and well rounded fine to medium gravel. Large stockpiles of pit run fine to medium gravel were noted in pit no. 5. Generally, the sand portion of the aggregate in pit nos. 5 and 22 is much coarser than the sand fraction located in the other pits.

Ministry of Transportation aggregate suitability data indicates that in the past aggregate from this deposit was acceptable for G.B.C. B and C, and for 16 mm Crushed Types A and B. Blending was employed in order to produce high-specification fine aggregate products. A portable plant once produced crusher-run G.B.C. A gravel from a coarse aggregate area in pit no. 6 (Hewitt and Cowan 1969). According to Ministry of Transportation data, the Edenvale Airfield was supplied with products from this pit during construction.

The remaining Algonquin beach deposits in the township make up Resource Area 2b and are generally located north of Resource Area 1. These deposits are relatively small and no sand and gravel pits have been developed in them. However, excavations for a recently built home located in one of the larger deposits revealed a 5- to 6-foot (1.5 to 2 m) exposure of well rounded fine to coarse aggregate interstratified with clean coarse sand. The gravel content was estimated to range between 30 and 40 percent.

Selected Areas 2a and 2b occupy 230 acres (93 ha), exclusive of licenced properties. Deletions for cultural constraints and previous extraction leave 145 acres (59 ha) currently available. The total sand and gravel resources contained in both resource areas is estimated to be 5 million tons (5 million tonnes). King's Highway 26 crosses Area 2a and provides an excellent haulage route for aggregate transport.

SELECTED SAND AND GRAVEL RESOURCE AREA 3

Resource Area 3 is located in the southwestern corner of the township. The resource area consists of three glaciofluvial outwash gravel deposits, one of which is buried by a thin cover of older alluvium and another slightly modified by subsequent aqueous erosion (Burwasser, in preparation, 1974a).

Pit no. 17 is located in the modified outwash deposit that extends northwestward into Nottawasaga Township. This deposit forms part of the rather extensive Creemore channel outwash (Burwasser, in preparation). Although mostly overgrown at the time of investigation, pit 17 exhibited a 10-foot (3 m) face of stratified, medium to coarse clean sand and well rounded, fine to coarse aggregate. Approximately 1 foot (0.3 m) of silty sand was stripped from the surface before encountering outwash gravel. A sample of the material taken from the pit revealed more than 50 percent gravel. Gradation tests performed on the material (Figure 4a and 4b) indicate that it is suitable for a wide range of granular base course products and a number of high-specification hot-laid sand uses. Additional field and subsurface investigations are recommended for the identification of specific areas within which there may be a high probability of locating good-quality crushable gravel.

Resource Area 3 occupies 70 acres (28 ha). Deletions for cultural constraints and previous extraction leave 30 acres (12 ha) currently available. Using a conservative estimate of 10 feet (3 m) for deposit thickness, sand and gravel resources are estimated to be 1 million tons (1 million tonnes).

SAND AND GRAVEL RESOURCE AREAS OF SECONDARY SIGNIFICANCE

Two glaciolacustrine beach deposits located immediately south of the town of Wasaga Beach have been selected at the secondary level of significance. These 10- to 15-foot (3 to 5 m) high remnant bluffs were formed by glacial Lake Nipissing. The deposits extend eastward and westward into Flos and Nottawasaga Townships, respectively. Pit nos. 26 to 30 were developed in the larger deposit and are now largely overgrown. However, in places the pit faces expose subangular to rounded, fine to medium gravel with interstratified fine to coarse sand.

Data obtained from the Ministry of Transportation indicate that the aggregate from pit no. 30 has been used for G.B.C. C. However, the sand tends to grade fine for hot-laid and sand asphalt course uses. A sample of the material from pit no. 29, taken at the time of investigation, revealed 17 percent gravel. Gradation tests performed on the sampled material indicate that it is suitable for G.B.C. C and borderline for G.B.C. B. (Figure 5a). If the excess fines were removed from the material some high-specification products such as hot-laid sand may be produced (Figure 5b).

SAND AND GRAVEL RESOURCES OF TERTIARY SIGNIFICANCE

A final area of interest for aggregate potential exists immediately adjacent to the town of Wasaga Beach near Springhurst Beach. This area forms part of the lacustrine barrier island complex discussed by Martini (1974, 1975). This barrier complex can be subdivided into three environments: the barrier consisting of sandy gravel or sand beaches associated with Lake Nipissing; the lagoon, located behind the barrier along the Nottawasaga River; and the dunes that cap the barrier system. A pit is located in this barrier complex (Lots 1 and 2, Conc. 14). At the time of field investigation the pit face exposed a 30- to 50-foot (9 to 15 m) face of well sorted, fine to medium dune sand showing large scale crossbedding. The dune sand overlay 10 to 12 feet (3 to 4 m) of well developed and well sorted sandy gravel associated with a beach deposit formed during the early stages of Lake Nipissing. Materials in this face consisted of medium to coarse sand interstratified with well rounded fine to medium gravel. Lenses of open work fine gravel were noted in this portion of the property. Gravel contents ranged from less than 5 percent in the overlying dunes (SN-SS-1a) to 30 to 55 percent in the lower beach area (SN-SS-1b).

Aggregate from this property as well as from the immediate area has been used for G.B.C. A, B and C, and concrete stone. A portable plant once produced 3/4 inch (19 mm) and 3/8 inch (9.5 mm) crushed stone and crusher-run gravel (Hewitt and Cowan 1969). Sand blending is required in order to produce higher specification products such as hot-laid sand and concrete sand.

A geophysics traverse line (SN-GT-3) completed on the floor of the pit confirmed the presence of an additional 5 to 10 feet (1.5 to 3 m) of beach gravel and sand before encountering a possible compact till (Table 8).

BEDROCK GEOLOGY

Bedrock underlying Sunnidale Township consists of the Verulam, Lindsay and Blue Mountain Formations of Middle and Upper Ordovician age. The distribution of these formations is shown on Map 3 (after Liberty 1969; Russell and Telford 1983; Telford 1976).

The oldest bedrock unit in the township is the Verulam Formation. Generally it underlies the eastern part of the township. The formation consists of approximately 200 feet (61 m) of fossiliferous, pure to impure grey limestone, interbedded with thin to thick shale layers (Liberty 1969). This unit has been quarried in other parts of southern Ontario to produce cement. The stone is, however, unsuitable for crushed stone production because of low abrasion and freeze-thaw resistance and the presence of shaly interbeds (Dolar-Mantuani 1975).

Overlying the Verulam Formation is the Lindsay Formation which occupies almost all of the remainder of the township. The formation consists of two members: the lower member which is a grey argillaceous limestone containing numerous shaly partings, particularily in the upper portion of the unit; and the Collingwood Member (Russell and Telford 1983) which is brownish-black, organic-rich, interbedded calcareous shale and limestone. The formation is generally unsatisfactory as a source of concrete aggregate and probably also for less demanding uses (Dolar-Mantuani 1975), but the lower member has been quarried elsewhere for use as a raw material in cement production.

The youngest bedrock strata in the township is the the Blue Mountain Formation, which occupies a small area in the southwestern corner of the township and which overlies the Lindsay Formation. The unit consists of blue-gray, noncalcareous shale, which is generally not suitable for the production of concrete aggregate. Its value for expanded aggregate has not yet been determined (Guillet 1977).

On a regional scale the formations dip gently to the southwest approximately 25 feet to the mile (5 m to the kilometre) (Liberty 1969). Based on this information, the bedrock topography in Sunnidale Township is expected to be relatively flat. The thickness of surficial drift overlying the bedrock is generally in excess of 100 feet (30 m) and east of Sunnidale Corners the drift cover exceeds 300 feet (91 m). The working of any of these bedrock units is, therefore, not practical.

SUMMARY

The sand and gravel deposits of Sunnidale Township are primarily the product of glacial activity that occurred during the Great Ice Age, as well as of the postglacial deposition of dune sand. All of the glacial Lake Algonquin beach deposits and deposits of glaciofluvial outwash gravel have been selected for possible resource protection and/or development at the primary level of significance. These deposits are generally capable of producing high-quality coarse aggregate suitable for the production of granular base course materials and hot-mix asphalt paving mixes providing suitable processing techniques are employed. In addition, two beach deposits related to

glacial Lake Nipissing have been selected at the secondary level.

Bedrock units that underlie Sunnidale Township include the Verulam, Lindsay and Blue Mountain Formations. Thick drift restricts any of these formations from being selected for possible resource protection, and the township must rely totally on surficial aggregate deposits.

Enquiries regarding the Aggregate Resources Inventory of Sunnidale Township should be directed to the Aggregate Assessment Office, Engineering and Terrain Geology Section, Ontario Geological Survey, Mines and Minerals Division, Ministry of Northern Development and Mines, Room M1B-45, Macdonald Block, Queen's Park, 900 Bay Street, Toronto, Ontario M7A 1W4 [Tel. (416) 965-1663], or to the Resident Geologist, Mines and Minerals Division, Ministry of Northern Development and Mines, P.O. Box 5463, 659 Exeter Road, London, Ontario, N6A 4L6 [Tel. (519) 661-2773], or to the Ontario Ministry of Natural Resources at the Huronia District Office, Midhurst, Ontario, L0L 1X0 [Tel. (705) 728-2900].

TABLE 1. TOTAL SAND AND GRAVEL RESOURCES, SUNNIDALE TOWNSHIP*.

1 Class No.	2 Deposit Type (see Appendix C)	3 Areal Extent Acres (Hectares)	4 Original Tonnage Millions of Tons (Tonnes)
1	S-OW	370 (150)	18 (16)
	S-WD	100 (40)	10 (9)
2	G-LB	740 (300)	28 (25)
	G-OW	30 (12)	1 (1)
	G-OW (buried deposit)	40 (16)	1 (1)
	S-LB	260 (105)	8 (7)
	S-LD	3750 (1520)	141 (128)
	S-LP	11,000 (4450)	410 (370)
3	G-LB	40 (16)	1 (1)
	S-LB	32 (13)	1 (1)
	S-LP	385 (156)	8 (7)
4	G-LB	15 (6)	<1 (<1)
	S-LP	55 (22)	1 (1)
		16,800 (6800)	630 (570)

*Identified deposit areas within the town of Wasaga Beach, Wasaga Beach Provincial Park and the Department of National Defense Bases have been omitted on all tables.

N.B. Minor variations in all tables are caused by rounding of data.

TABLE 2. SAND AND GRAVEL PITS, SUNNIDALE TOWNSHIP.

1 No.	2 Ministry of Transportation No.	3 Owner/ Operator	4 Lot	5 Con.	6 Licenced Areas Acres (Hectares)	7 Face Height Feet (Metres)	8 % Gravel
LICENCED PITS							
1	C11-107	The Township of Sunnidale	Pt.1	3	64.0 (25.9)	5-10 (1.5-3)	30-40 mainly sand with gravel pockets
2	-	Martin Ready-Mix & Materials Ltd.	Pt.S1/2 2	4	11.8 (4.8)	8-10 (2-3)	<10 sand source
3	C11-49 C11-59	Martin Ready-Mix & Materials Ltd.	Pt.2	4	112.9 (45.7)	10-15 (3-5)	30-50 variable
4	-	Martin Ready-Mix & Materials Ltd.	Pt.4 Pt.N1/2 5	4	103.8 (42.0)	8-15 (2-5)	30 variable (western section)
5	-	Martin Ready-Mix & Materials Ltd.	14 17	9 ESR	131.4 (53.2)	5-15 (1.5-5)	20-35 largely overgrown, & water filled in sections
6	-	Wasaga Sand & Gravel Ltd.	16&17	10	55.0 (22.2)	10-25 (3-8)	20-35 variable & partially overgrown
					478.9 (193.8)		
UNLICENCED PITS*							
7	-	Unknown	25	2WSR		5 (1.5)	- sand source, pond rehabilitation
8	-	Unknown	12	3		5 (1.5)	- sand source, overgrown
9	-	Unknown	7	3		10-15 (3-5)	- sand source, partially overgrown
10	-	Unknown	11	1		15-20 (5-6)	- sand source
11	-	Unknown	9	1		3-5 (1-2)	- sand source, partially overgrown
12	-	Unknown	W1/4 9	1		5 (1.5)	- sand source, overgrown
13	-	Unknown	6	1		5-15 (1.5-5)	- sand source

*Abandoned pits or wayside pits operating on demand under authority of a permit.

TABLE 2. SAND AND GRAVEL PITS, SUNNIDALE TOWNSHIP.

1 No.	2 Ministry of Transportation No.	3 Owner/ Operator	4 Lot	5 Con.	6 Licenced Areas Acres (Hectares)	7 Face Height Feet (Metres)	8 % Gravel
14	-	Unknown	6	1		8-10 (2-3)	- sand source
15	-	Unknown	6	1		5 (1.5)	- sand source, overgrown
16	-	Unknown	5	1		3-10 (1-3)	<5 overgrown
17	-	Unknown	1	1		10 (3)	30-55 overgrown
18	C11-53	Cook Const. Company Ltd.	1&2	4		8-10 (2-3)	30-40 partially overgrown
19	-	Simcoe County	4	4		5-10 (1.5-3)	30-40 variable, overgrown
20	-	Unknown	9	4		3 (1)	- sand source, overgrown
21	B3-40	Manvel King Paving	12	9		5-10 (1.5-3)	20-30 largely depleted and overgrown
22	B3-75	Lougheed	15	9		5-10 (1.5-3)	20-30 overgrown and largely depleted
23	B3-144	Ivan Daley	W1/2 16	9		5-10 (1.5-3)	20-35
24	-	Unknown	SE1/4 15	10		5 (1.5)	- overgrown
25	-	Unknown	14	12		5 (1.5)	- overgrown
26	-	Unknown	13	12		5 (1.5)	- overgrown
27	-	Unknown	12	13		5 (1.5)	<25 partially overgrown
28	-	Unknown	9	13		10 (3)	20-30 overgrown
29	-	Unknown	8	13		5 (1.5)	10-20
30	C11-86	Unknown	7	13		5-10 (1.5-3)	<20 overgrown

TABLE 3. SELECTED SAND AND GRAVEL RESOURCE AREAS, SUNNIDALE TOWNSHIP.

1 Deposit No.	2 Unlicenced Area Acres (Hectares)	3 Cultural Setbacks Acres (Hectares)	4 Extracted Area Acres (Hectares)	5 Available Area Acres (Hectares)	6 Estimated Deposit Thickness Feet (Metres)	7 Available Aggregate Millions of Tons (Tonnes)
1	200 (81)	80 (32)	30 (12)	90 (36)	15 (5)	3 (3)
2a	170 (69)	20 (8)	45 (18)	105 (42)	15 (5)	4 (4)
2b	60 (24)	20 (8)	0 (0)	40 (16)	5 (2)	1 (1)
	230 (93)	40 (16)	45 (18)	145 (59)		5 (5)
3	70 (28)	35 (14)	5 (2)	30 (12)	10 (3)	1 (1)
	500 (202)	155 (63)	80 (32)	265 (107)		9 (8)

TABLE 4. TOTAL IDENTIFIED BEDROCK RESOURCES, SUNNIDALE TOWNSHIP.

1 **DRIFT THICKNESS** Feet (Metres)	2 **FORMATION**	3 **ESTIMATED DEPOSIT THICKNESS** Feet (Metres)	4 **AREAL EXTENT** Acres (Hectares)	5 **ORIGINAL TONNAGE** Millions of Tons (Tonnes)
		-NONE-		

TABLE 5. QUARRIES, SUNNIDALE TOWNSHIP.

1 NO.	2 MINISTRY OF TRANS-PORTATION NO.	3 OWNER/ OPERATOR	4 LOT	5 CON.	6 LICENCED AREA Acres (Hectares)	7 FACE HEIGHT Feet (Metres)
			-NONE-			

TABLE 6. SELECTED BEDROCK RESOURCE AREAS, SUNNIDALE TOWNSHIP.

1 **DEPOSIT NO.**	2 **DEPTH OF OVERBURDEN** Feet (Metres)	3 **UNLICENCED AREA** Acres (Hectares)	4 **CULTURAL SETBACKS** Acres (Hectares)	5 **EXTRACTED AREA** Acres (Hectares)	6 **AVAILABLE AREA** Acres (Hectares)	7 **ESTIMATED WORKABLE THICKNESS** Feet (Metres)	8 **AVAILABLE RESOURCES** Millions of Tons (Tonnes)
-NONE-							

TABLE 7. SUMMARY OF TEST HOLE DATA, SUNNIDALE TOWNSHIP.

-NONE-

TABLE 8. SUMMARY OF GEOPHYSICS DATA, SUNNIDALE TOWNSHIP

Line Number: SN-GT-1
Line Direction: 90°
Method: Hammer Seismic
Location: Lot 8, Conc. 3 (in County Reforestation Area)
Elevation: Approx. 725 feet (221 m) a.s.l.
Geology: Lacustrine delta
Seismic Data:

Number of Layers:	2
Layer Velocities:	V_1 = 1250 ft./sec. (380 m/sec.)
	V_2 = 5000 ft./sec. (1520 m/sec.)
Layer Thickness:	D_1 = 13 feet (4 m)

Interpretation:
Layer 1: Approx. 13 feet (4 m) of clean fine to medium sand (confirmed by SN-DS-1)
Layer 2: Till possibly encountered

Line Number: SN-GT-2
Line Direction: 360°
Method: Hammer Seismic
Location: Lot 1, Conc. 3 (on floor of licenced pit no. 1)
Elevation: Approx. 750 feet (229 m) a.s.l.
Geology: Lake Algonquin glaciolacustrine beach sediments
Seismic Data:

Number of Layers:	2
Layer Velocities:	V_1 = 1430 ft./sec. (435 m/sec.)
	V_2 = 3350 ft./sec. (1020 m/sec.)
Layer Thickness:	D_1 = 6.5 feet (2.0 m)

Interpretation:
Layer 1: Approximately 6.5 feet (2.0 m) Sand
Layer 2: Water table encountered and velocities increased to approx. 3350 feet/sec. (1020 m/sec.)

Line Number: SN-GT-3
Line Direction: 360°
Method: Hammer Seismic
Location: Lot 2, Conc. 14. (on floor of licenced pit below dune sands that overlie a lacustrine beach)
Elevation: Approx. 600 feet (183 m) to 625 feet (190 m) a.s.l.
Geology: Part of the "Barrier Island Complex" where eolian dunes overlie a sandy-gravelly beach
Seismic Data:

Number of Layers:	2
Layer Velocities:	V_1 = 1670 ft./sec. (510 m/sec.)
	V_2 = 5000 ft./sec. (1520 m/sec.)
Layer Thickness:	D_1 = 5 to 10 feet (1.5 to 3 m)

Interpretation:
Layer 1: Approx. 5 to 10 feet (1.5 to 3 m) of beach gravel and sand
Layer 2: Compact till (water well data in this immediate area indicates the presence of a stony clayey silt material underlying beach sediments)

TABLE 9. AGGREGATE QUALITY TEST DATA, SUNNIDALE TOWNSHIP.

-NONE-

TABLE 10. DESCRIBED SECTIONS, SUNNIDALE TOWNSHIP.

Described Section Number: SN-DS-1
Location: Sunnidale Township, Lot 8, Conc. 3
Elevation: Approx. 725 feet (221 m) a.s.l.

Depth Feet (metres)	Description
0-15 (0-5)	fine to medium clean **sand**

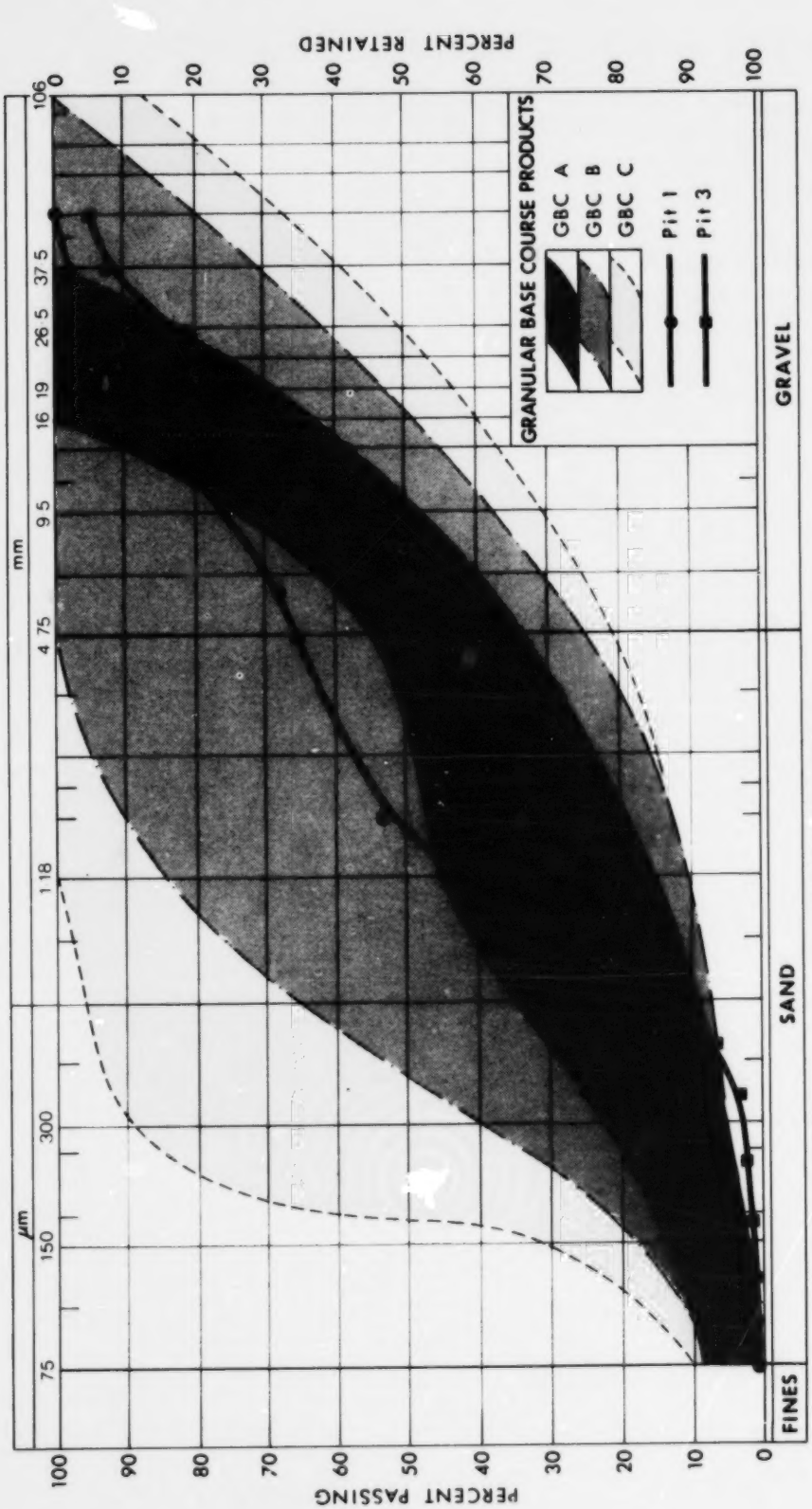


FIGURE 2a: AGGREGATE GRADING CURVES, SUNNIDALE TOWNSHIP:

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

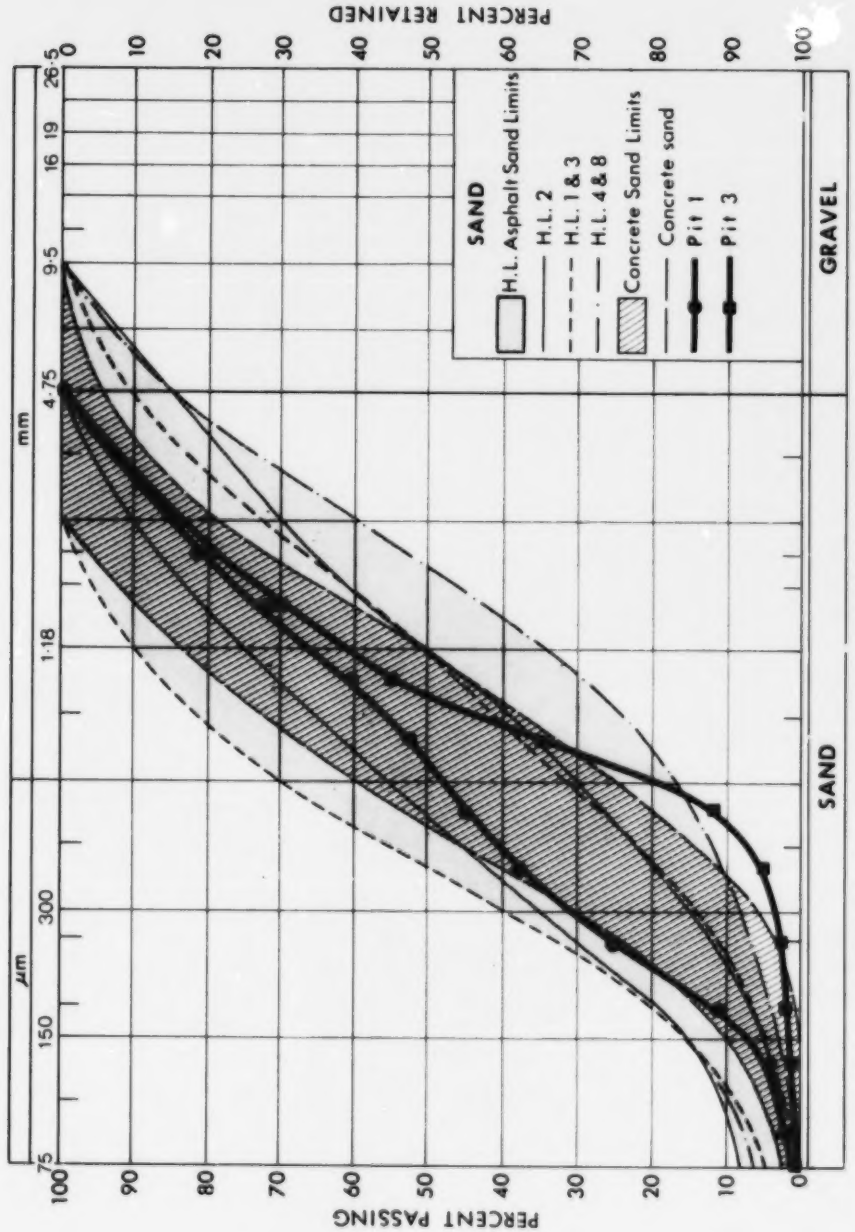


FIGURE 2b: AGGREGATE GRADING CURVES, SUNNIDALE TOWNSHIP;

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Forms 1002, 1979 and 1003, 1981).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

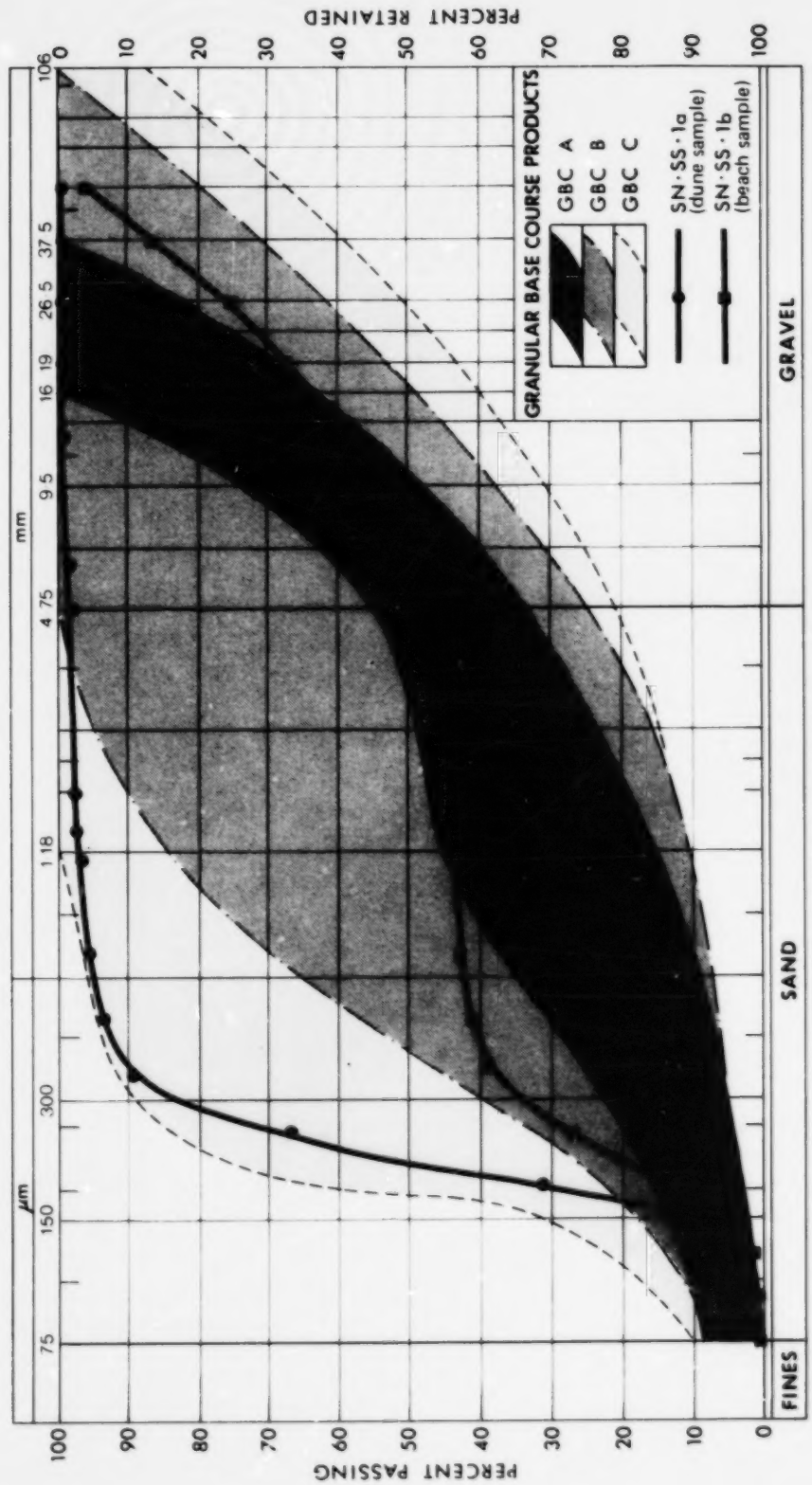


FIGURE 3a: AGGREGATE GRADING CURVES, SUNNIDALE TOWNSHIP:

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

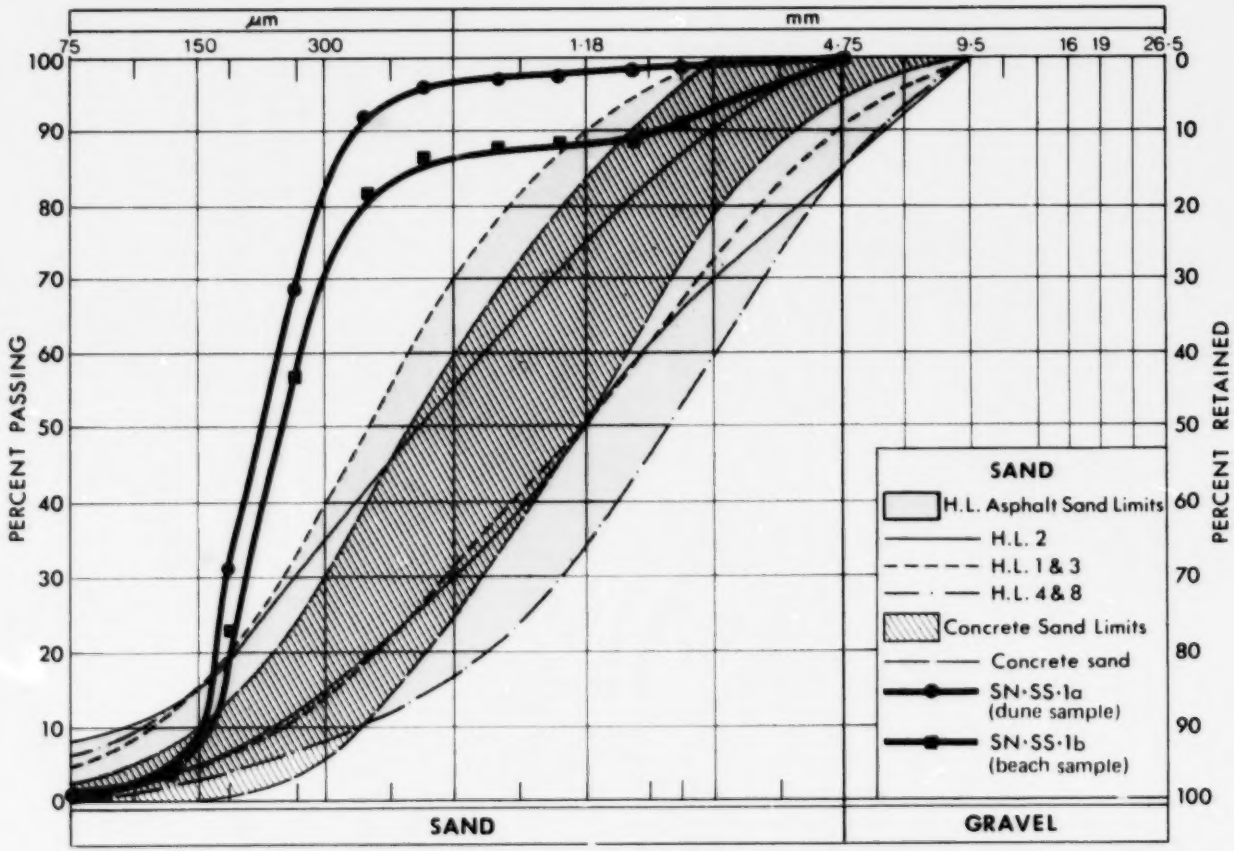


FIGURE 3b: AGGREGATE GRADING CURVES, SUNNIDALE TOWNSHIP;

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Forms 1002, 1979 and 1003, 1981).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

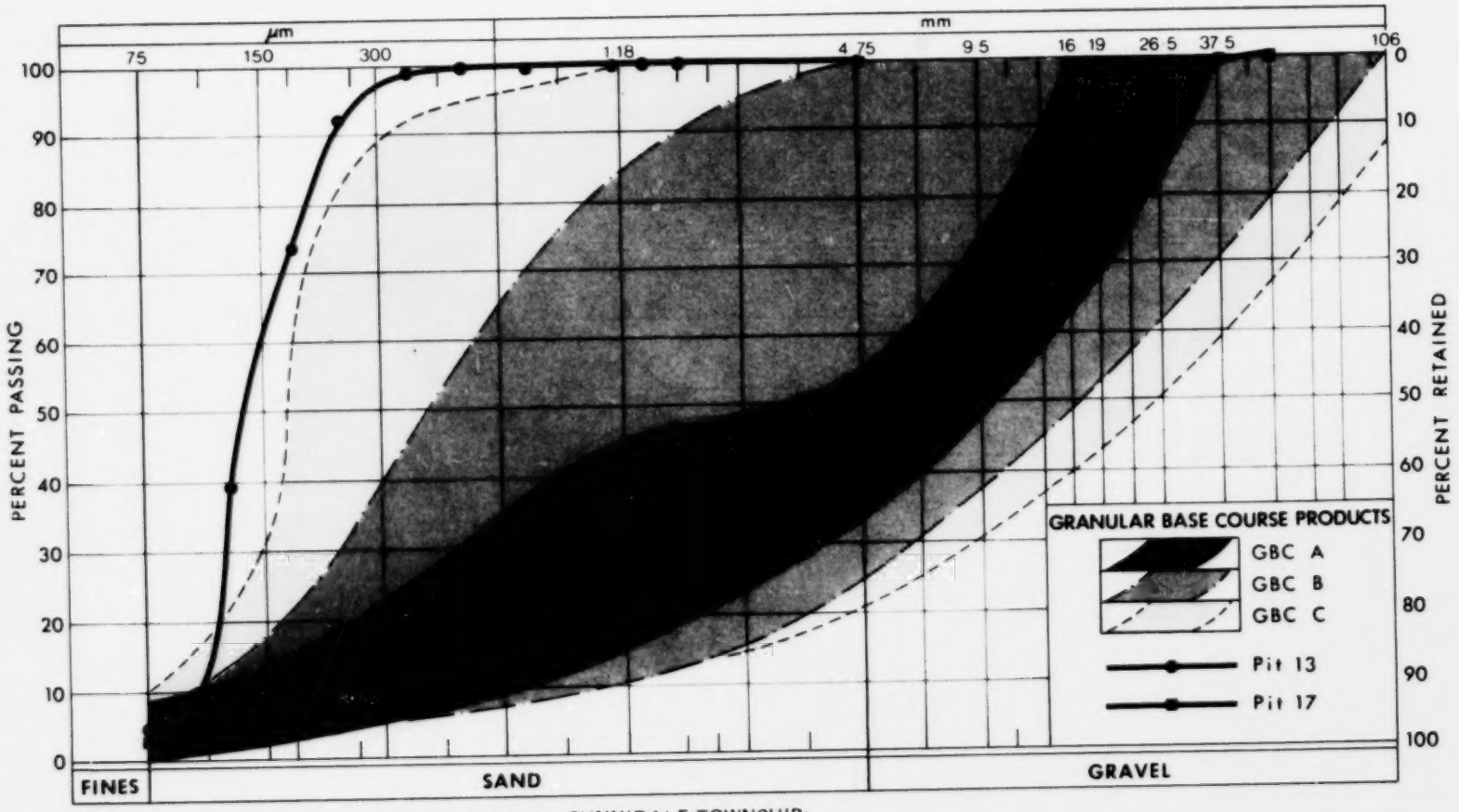


FIGURE 4a. AGGREGATE GRADING CURVES, SUNNIDALE TOWNSHIP;

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

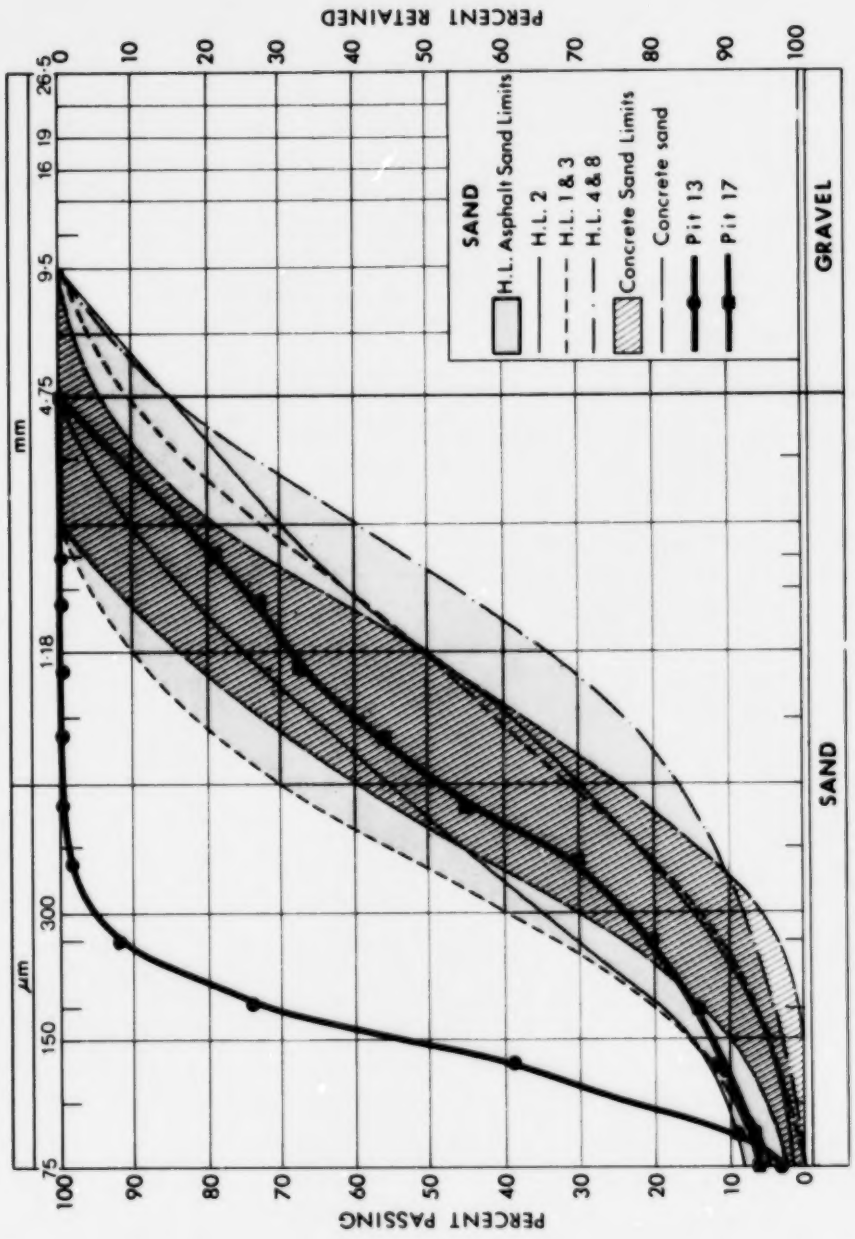


FIGURE 4b: AGGREGATE GRADING CURVES, SUNNIDALE TOWNSHIP:

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Forms 1002, 1979 and 1003, 1981).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

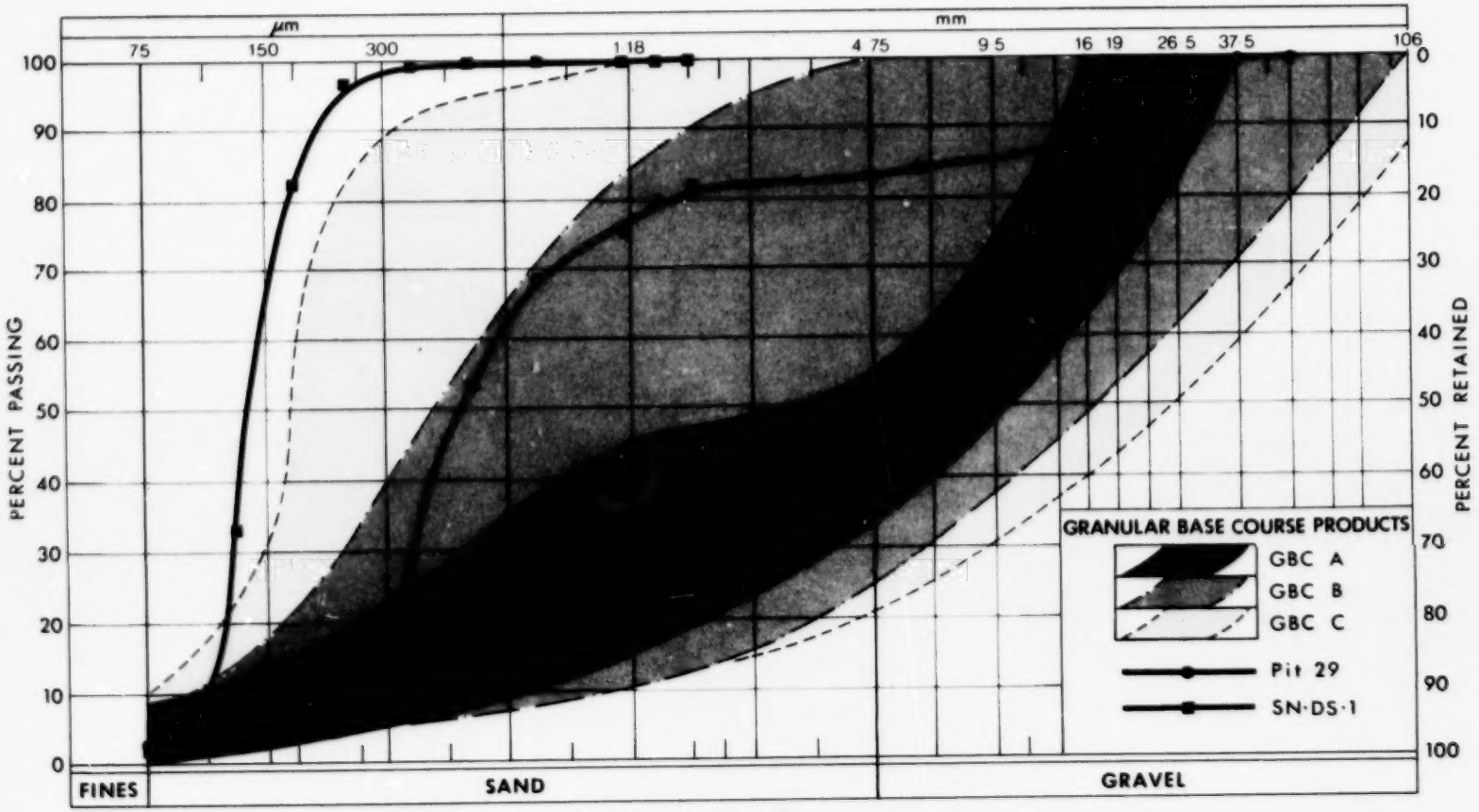


FIGURE 5a: AGGREGATE GRADING CURVES, SUNNIDALE TOWNSHIP;

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

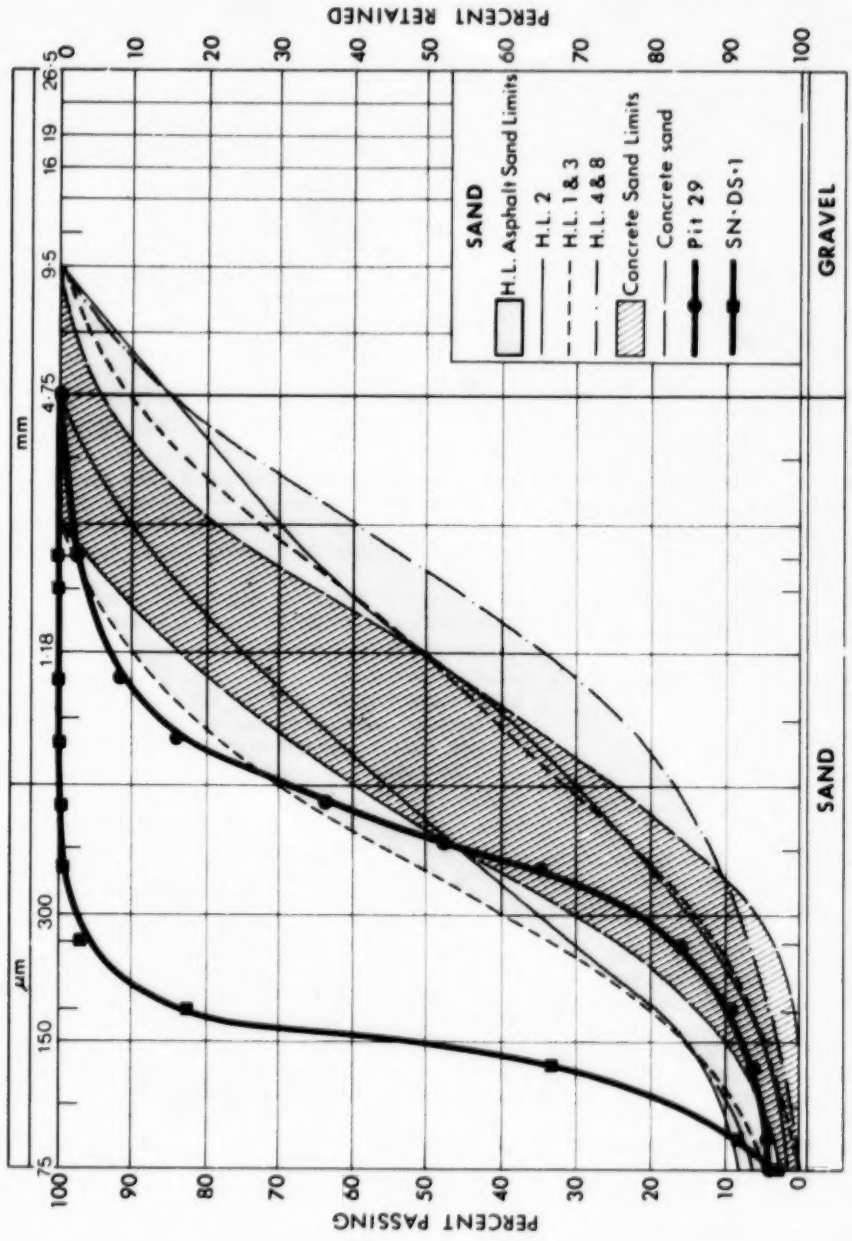


FIGURE 5b: AGGREGATE GRADING CURVES, SUNNIDALE TOWNSHIP.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Forms 1002, 1979 and 1003, 1981).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

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Appendix A — Suggested Additional Reading

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Appendix B — Glossary

Abrasion resistance: Tests such as the Los Angeles abrasion test are used to measure the ability of aggregate to resist crushing and pulverizing under conditions similar to those encountered in processing and use. Measuring resistance is an important component in the evaluation of the quality and prospective uses of aggregate. Hard, durable material is preferred for road building.

Absorption capacity: Related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate.

Aggregate: Any hard, inert, construction material (sand, gravel, shells, slag, crushed stone or other mineral material) used for mixing in various-sized fragments with a cement or bituminous material to form concrete, mortar, etc., or used alone for road building or other construction. Synonyms include mineral aggregate and granular material.

Aggregate Abrasion Value: This test directly measures the resistance of aggregate to abrasion with silica sand and a steel disk. The higher the value, the lower the resistance to abrasion. For high quality asphalt surface course uses, values of less than 6 are desireable.

Alkali-aggregate reaction: A chemical reaction between the alkalis of portland cement and certain minerals found in rocks used for aggregate. Alkali-aggregate reactions are undesirable because they can cause expansion and cracking of concrete. Although perfectly suitable for building stone and asphalt applications, alkali-reactive aggregates should be avoided for structural concrete uses.

Beneficiation: Beneficiation of aggregates is a process or combination of processes which improves the quality (physical properties) of a mineral aggregate and is not part of the normal processing for a particular use, such as routine crushing, screening, washing or classification. Heavy media separation, jigging, or application of special crushers (e.g. "cage mill") are usually considered processes of beneficiation.

Blending: Required in cases of extreme coarseness, fineness, or other irregularities in the gradation of unprocessed aggregate. Blending is done with approved sand-sized aggregate in order to satisfy the gradation requirements of the material.

Bulk Relative Density: An aggregate with low relative density is lighter in weight than one with a high relative density. Low relative density aggregates (less than about 2.5) are often non-durable for many aggregate uses.

Cambrian: The first period of the Paleozoic Era, thought to have covered the time between 570 and 500 million years ago. The Cambrian precedes the Ordovician Period.

Clast: An individual constituent, grain or fragment of a sediment or rock, produced by the mechanical weathering of larger rock mass. Synonyms include particle and fragment.

Crushable aggregate: Unprocessed gravel containing a minimum of 35 percent coarse aggregate larger than the No. 4 sieve (4.75 mm) as well as a minimum of 20 percent greater than the 26.5 mm sieve.

Deleterious lithology: A general term used to designate those rock types which are chemically or physically unsuited for use as construction or road-building aggregates. Such lithologies as chert, shale, siltstone and sandstone may deteriorate rapidly when exposed to traffic and other environmental conditions.

Devonian: A period of the Paleozoic Era thought to have covered the span of time between 395 and 345 million years ago, following the Silurian Period. Rocks formed in the Devonian Period are among the youngest found in Ontario.

Dolostone: A carbonate sedimentary rock consisting chiefly of the mineral dolomite and containing relatively little calcite (dolostone is also known as dolomite).

Drift: A general term for all unconsolidated rock debris transported from one place and deposited in another, distinguished from underlying bedrock. In North America, glacial activity has been the dominant mode of transport and deposition of drift. Synonyms include overburden and surficial deposit.

Drumlin: A low, smoothly rounded, elongated hill, mound, or ridge composed of glacial materials. These landforms were formed beneath an advancing ice sheet, and were shaped by its flow.

Eolian: Pertaining to the wind, especially with respect to landforms whose constituents were transported and deposited by wind activity. Sand dunes are an example of an eolian landform.

Fines: A general term used to describe the size fraction of an aggregate which passes (is finer than) the No. 200 mesh screen (0.075 mm). Also described informally as "dirt", these particles are in the silt and clay size range.

Glacial lobe: A tongue-like projection from the margin of the main mass of an ice cap or ice sheet. During the Pleistocene Epoch several lobes of the Laurentide continental ice sheet occupied the Great Lakes basins. These lobes advanced then melted back numerous times during the Pleistocene, producing the complex arrangement of glacial material and landforms found in southern Ontario.

Gradation: The proportion of material of each particle size, or the frequency distribution of the various sizes which constitute a sediment. The strength, durability, permeability and stability of an aggregate depend to a great extent on its gradation. The size limits for different particles are as follows:

Boulder	more than 200 mm
Cobbles	75-200 mm
Coarse Gravel	26.5-75 mm
Fine Gravel	4.75-26.5 mm
Coarse Sand	2-4.75 mm
Medium Sand	0.425-2 mm
Fine Sand	0.075-0.425 mm
Silt, Clay	less than 0.075 mm

Granular base course: Components of the pavement structure of a road, which are placed on the subgrade and are designed to provide strength, stability and drainage, as well as support for surfacing materials. Several types have been defined: Granular Base Course A consists of crushed and processed aggregate and has relatively stringent quality standards in comparison to Granular Base Course B and C which are usually pit-run or other unprocessed aggregate.

Hot-laid (or asphaltic) aggregate: Bituminous, cemented aggregates used in the construction of pavements either as surface or bearing course (H.L. 1, 3 and 4), or as binder course (H.L. 2 and 8) used to bind the surface course to the underlying granular base course.

Lithology: The description of rocks on the basis of such characteristics as color, structure, mineralogic composition and grain size. Generally, the description of the physical character of a rock.

Los Angeles Abrasion and Impact Test: This test measures the resistance to abrasion and the impact strength of aggregate. This gives an idea of the breakdown that can be expected to occur when an aggregate is stockpiled, transported, and placed. Values less than about 35 percent indicate potentially satisfactory performance for most concrete and asphalt uses. Values of more than 45 percent indicate that the aggregate may be susceptible to excessive breakdown during handling and placing.

Magnesium sulphate soundness test: This test is designed to simulate the action of freezing and thawing on aggregates. Those aggregates which are susceptible to freezing and thawing will usually break down and give high losses in this test. Values greater than about 12 to 15 percent indicate potential problems for concrete and asphalt coarse aggregate.

Meltwater channel: A drainage way, often terraced, produced by water flowing away from a melting glacier margin.

Ordovician: an early period of the Paleozoic Era thought to have covered the span of time between 500 and 435 million years ago.

Paleozoic era: One of the major divisions of the geologic time scale thought to have covered the time between 570 and 230 million years ago, the Paleozoic Era (or Ancient Life Era) is subdivided into six geologic periods, of which only four (Cambrian, Ordovician, Silurian and Devonian) can be recognized in southern Ontario.

Petrographic examination: Individual aggregate particles in a sample are divided into categories good, fair, poor, and deleterious, based on their rock type (petrography) and knoledge of past field performance. A petrographic number (PN) is calculated. The higher the PN, the lower the quality of the aggregate.

Pleistocene: An epoch of the recent geological past including the time from approximately 2 million years ago to 7000 years ago. Much of the Pleistocene was characterized by extensive glacial activity and is popularly referred to as the "Great Ice Age".

Polished Stone Value: This test measures the frictional properties of aggregates after 6 hours of abrasion and polishing with an emery abasive. The higher the PSV, the higher the frictional properties of the aggregate. Values less than 45 indicate marginal frictional properties, while values greater than 55 indicate excellent frictional properties.

Possible resource: Reserve estimates based largely on broad knowledge of the geological character of the deposit and for which there are few, if any, samples or measurements. The estimates are based on assumed continuity or repetition for which there are reasonable geological indications.

Precambrian: The earliest geological period extending from the consolidation of the earth's crust to the beginning of the Cambrian.

Shale: A fine-grained, sedimentary rock formed by the consolidation of clay, silt or mud and characterized by well developed bedding planes, along which the rock breaks readily into thin layers. The term shale is also commonly used for fissile claystone, siltstone and mudstone.

Silurian: An early period of the Palezoic Era thought to have covered the time between 435 and 395 million years ago. The Silurian follows the Ordovician Period and precedes the Devonian Period.

Soundness: The ability of the components of an aggregate to withstand the effects of various weathering processes and agents. Unsound lithologies are subject to disintegration caused by the expansion of absorbed solutions. This may seriously impair the performance of road-building and construction aggregates.

Till: Unsorted and unstratified rock debris, deposited directly by glaciers, and ranging in size from clay to large boulders.

Wisconsinan: Pertaining to the last glacial period of the Pleistocene Epoch in North America. The Wisconsinan began approximately 100 000 years ago and ended approximately 7000 years ago. The glacial deposits and landforms of southern Ontario are predominantly the result of glacial activity during the Wisconsinan Stage.

Appendix C — Geology of Sand and Gravel Deposits

The type, distribution, and extent of sand and gravel deposits in southern Ontario are the result of extensive glacial and glacially influenced activity in Wisconsinan time during the Pleistocene Epoch, approximately 100 000 to 7000 years ago. The deposit types reflect the different depositional environments that existed during the melting and retreat of the continental ice masses, and can readily be differentiated on the basis of their morphology, structure, and texture. The deposit types are described below.

GLACIOFLUVIAL DEPOSITS

These deposits can be divided into two broad categories: those that were formed in contact with (or in close proximity to) glacial ice, and those that were deposited by meltwaters carrying materials beyond the ice margin.

Ice-Contact Terraces (ICT): These are glaciofluvial features deposited between the glacial margin and a confining topographic high, such as the side of a valley. The structure of the deposits may be similar to that of outwash deposits, but in most cases the sorting and grading of the material is more variable and the bedding is discontinuous because of extensive slumping. The probability of locating large amounts of crushable aggregate is moderate, and extraction may be expensive because of the variability of the deposits both in terms of quality and grain size distribution.

Kames (K): Kames are defined as mounds of poorly sorted sand and gravel deposited by meltwater in depressions or fissures on the ice surface or at its margin. During glacial retreat, the melting of supporting ice causes collapse of the deposits, producing internal structures characterized by bedding discontinuties. The deposits consist mainly of irregularly bedded and crossbedded, poorly sorted sand and gravel. The present forms of the deposits include single mounds, linear ridges (crevasse fillings) or complex groups of landforms. The latter are occasionally described as "undifferentiated ice-contact stratified drift" (IC) when detailed subsurface information is unavailable. Since kames commonly contain large amounts of fine-grained material and are characterized by considerable variability, there is generally a low to moderate probability of discovering large amounts of good quality, crushable aggregate. Extractive problems encountered in these deposits are mainly the excessive variability of the aggregate and the rare presence of excess fines (silt- and clay-sized particles).

Eskers (E): Eskers are narrow, sinuous ridges of sand and gravel deposited by meltwaters flowing in tunnels within or at the base of glaciers, or in channels on the ice surface. Eskers vary greatly in size. Many, though not all eskers consist of a central core of poorly sorted and stratified gravel characterized by a wide range in grain size. The core material is often draped on its flanks by better sorted and stratified gravel. The deposits have a high probability of containing a large proportion of crushable aggregate, and since they are generally built above the surrounding ground surface, are convenient extraction sites. For these reasons esker deposits have been traditional aggregate sources throughout Ontario, and are significant components of the total resources of many areas.

Some planning constraints and opportunities are inherent in the nature of the deposits. Because of their linear nature, the deposits commonly extend across several property boundaries leading to unorganized extractive development at numerous small pits. On the other hand, because of their form, eskers can be easily and inexpensively extracted and are amenable to rehabilitation and sequential land use.

Undifferentiated Ice-Contact Stratified Drift (IC): This designation may include deposits from several ice-contact, depositional environments which usually form extensive, complex landforms. It is not feasible to identify individual areas of coarse-grained material within such deposits because of their lack of continuity and grain size variability. They are given a qualitative rating based on existing pit and other subsurface data.

Outwash (OW): Outwash deposits consist of sand and gravel laid down by meltwaters beyond the margin of the ice lobes. The deposits occur as sheets or as terraced valley fills (valley trains) and may be very large in extent and thickness. Well developed outwash deposits have good horizontal bedding and are uniform in grain size distribution. Outwash deposited near the glacier's margin is much more variable in texture and structure. The probability of locating useful crushable aggregates in outwash deposits is moderate to high depending on how much information on size, distribution and thickness is available.

Alluvium (AL): Alluvium is a general term for clay, silt, sand, gravel, or similar unconsolidated material deposited during postglacial time by a stream as sorted or semi-sorted sediment, on its bed or on its floodplain. The probability of locating large amounts of crushable aggregate in alluvial deposits is low, and they have generally low value because of the presence of excess silt- and clay-sized material. There are few large postglacial alluvium deposits in Ontario.

GLACIOLACUSTRINE DEPOSITS

Glaciolacustrine Beach Deposits (LB): These are relatively narrow, linear features formed by wave action at the shores of glacial lakes that existed at various times during the deglaciation of southern Ontario. Well developed lacustrine beaches are usually less than 20 feet (6 m) thick. The aggregate is well sorted and stratified and sand-sized material commonly predominates. The composition and size distribution of the deposit depends on the nature of the source material. The probability of obtaining crushable aggregate is high when the material is developed from coarse-grained materials such as a stony till, and low when developed from fine-grained materials. Beaches are relatively narrow, linear deposits, so that extractive operations are often numerous and extensive.

Glaciolacustrine Deltas (LD): These features were formed where streams or rivers of glacial meltwater flowed into lakes and deposited their suspended sediment. In southern Ontario such deposits tend to consist mainly of sand and abundant silt. However, in near-ice and ice-contact positions, coarse material may be present. Although deltaic deposits may be large, the probability of obtaining coarse material is generally low.

Glaciolacustrine Plains (LP): The nearly level surface marking the floor of an extinct glacial lake. The sediments which form the plain are predominantly fine to medium sand, silt, and clay, and were deposited in relatively deep water. Lacustrine deposits are generally of low value as aggregate sources because of their fine grain size and lack of crushable material. In some aggregate-poor areas, lacustrine deposits may constitute valuable sources of fill and some granular base course aggregate.

GLACIAL DEPOSITS

End Moraines (EM): These are belts of glacial drift deposited at, and parallel to, glacier margins. End moraines commonly consist of ice-contact stratified drift and in such instances are usually called kame moraines. Kame moraines commonly result from deposition between two glacial lobes (interlobate moraines). The probability of locating aggregates within such features is moderate to low. Exploration and development costs are high. Moraines may be very large and contain vast aggregate resources, but the location of the best areas within the moraine is usually poorly defined.

EOLIAN DEPOSITS

Windblown Deposits (WD): Windblown deposits are those formed by the transport and deposition of sand by winds. The form of the deposits ranges from extensive, thin layers to well developed linear and crescentic ridges known as dunes. Most windblown deposits in southern Ontario are derived from, and deposited on, pre-existing lacustrine sand plain deposits. Windblown sediments almost always consists of fine to coarse sand and are usually well sorted. The probabiltiy of locating crushable aggregate in windblown deposits is very low.

Appendix D — Geology of Bedrock Deposits

The purpose of this appendix is to familiarize the reader with the general bedrock geology of southern Ontario (Figure 6), and the potential uses of the various bedrock formations where known. The reader is cautioned against using this information for more specific purposes. The stratigraphic chart (Figure 7) is intended only to illustrate the stratigraphic sequences in particular geographic areas and should not be used as a regional correlation table.

The following description is arranged in ascending stratigraphic order, on a group and formation basis. Precambrian rocks are not discussed. Additional stratigraphic information is included for some formations where necessary. The publications and maps of the Ontario Geological Survey and the Geological Survey of Canada should be referred to for more detailed information. The composition, thickness, and uses of the formations are discussed. If a formation may be suitable for use as aggregate and aggregate suitability test data is available, the data has been included in the form of ranges. The following short forms have been used in presenting this data: PSV = Polished Stone Value, AAV = Aggregate Abrasion Value, $MgSO_4$ = Magnesium Sulphate Soundness Test (loss in percent), LA = Los Angeles Abrasion and Impact Test (loss in percent), Absn = Absorption (percent), BRD = Bulk Relative Density, PN (Asphalt & Concrete) = Petrographic Number for Asphalt and Concrete use.

The ranges are intended as a guide only and care should be exercised in extrapolating the information to specific situations. Aggregate suitability test data has been provided by the Ontario Ministry of Transportation.

Covey Hill Formation (Cambrian)

STRATIGRAPHY: lower formation of the Potsdam Group. COMPOSITION: interbedded non-calcareous feldspathic conglomerate and sandstone. THICKNESS: 0 to 45 feet (0 to 14 m). USES: has been quarried for aggregate in South Burgess Township, Leeds County.

Nepean Formation (Cambro-Ordovician)

STRATIGRAPHY: upper formation of the Potsdam Group. COMPOSITION: thin-bedded to massive quartz sandstone with some conglomerate interbeds and rare shaly partings. THICKNESS: 0 to 100 feet (0 to 30 m). USES: suitable as dimension stone; quarried at Philipsville and Forfar for silica sand; alkali-silica reactive in Portland cement concrete. AGGREGATE SUITABILITY TESTING: PSV = 54-68, AAV = 4-15, $MgSO_4$ = 9-32, LA = 44-90, Absn = 1.6-2.6, BRD = 2.38-2.50, PN (Asphalt & Concrete) = 130-140.

March Formation (Lower Ordovician)

STRATIGRAPHY: lower formation of the Beekmantown Group. COMPOSITION: interbedded quartz sandstone, dolomitic quartz sandstone, sandy dolostone and dolostone. THICKNESS: 60 to 197 feet (18 to 60 m). USES: quarried extensively for aggregate in area of subcrop and outcrop; alkali-silica reactive in Portland cement concrete; lower part of formation is an excellent source of skid-resistant aggregate. Suitable for use as facing stone and paving stone. AGGREGATE SUITABILITY TESTING: PSV = 55-60, AAV = 4-6, $MgSO_4$ = 1-17, LA = 15-38, Absn = 0.5-0.9, BRD = 2.61-2.65, PN (Asphalt & Concrete) = 110-150.

Oxford Formation (Lower Ordovician)

STRATIGRAPHY: upper formation of the Beekmantown Group. COMPOSITION: thin- to thick-bedded, microcrystalline to medium-crystalline, grey dolostone with thin shaley interbeds. THICKNESS: 200 to 335 feet (61 to 102 m). USES: quarried in the Brockville and Smith Falls areas and south of Ottawa for use as aggregate. AGGREGATE SUITABILITY TESTING: PSV = 47-48, AAV = 7-8, $MgSO_4$ = 1-4, LA = 18-23, Absn = 0.7-0.9, BRD = 2.74-2.78, PN (Asphalt & Concrete) = 105-120.

Rockcliffe Formation (Middle Ordovician)

STRATIGRAPHY: divided into lower member and upper (St. Martin) member. COMPOSITION: interbedded quartz sandstone and shale; interbedded shaly bioclastic limestone and shale predominating in upper member to the east. THICKNESS: 0 to 410 feet (0 to 125 m). USES: upper member has been quarried east of Ottawa for aggregate; lower member has been used as crushed stone; some high purity limestone beds in upper member may be suitable for use as fluxing stone and in lime production. AGGREGATE SUITABILITY TESTING: PSV = 58-63, AAV = 10-11, $MgSO_4$ = 12-40, LA = 25-28, Absn = 1.8-1.9, BRD = 2.55-2.62, PN (Asphalt & Concrete) = 122-440.

Shadow Lake Formation (Middle Ordovician)

STRATIGRAPHY: eastern Ontario - the basal unit of the Ottawa Group; central Ontario - overlain by the Simcoe Group. COMPOSITION: in eastern Ontario - silty and sandy dolostone with shale partings and minor interbeds of sandstone; in central Ontario - conglomerates, sandstones, and shales. THICKNESS: eastern Ontario - 7 to 10 feet (2 to 3 m); central Ontario - 0 to 40 feet (0 to 12 m). USES: potential source of decorative stone; very limited value as aggregate source.

Gull River Formation (Middle Ordovician)

STRATIGRAPHY: Part of the Simcoe Group (central Ontario) and Ottawa Group (eastern Ontario). In central and eastern Ontario the formation is subdivided into upper and lower members; west of Lake Simcoe it is presently subdivided into upper, middle and lower members. COMPOSITION: in central and eastern Ontario the lower member consists of alternating units of limestone, dolomitic limestone, and dolostone, the upper member consists of thin-bedded limestones with thin shale partings; west of Lake Simcoe the lower member is thin- to thick-bedded, interbedded, grey argillaceous limestone and buff to green dolostone whereas the upper and middle members are dense microcrystalline limestones with argillaceous dolostone interbeds. THICKNESS: 23 to 204 feet (7 to 62 m). USES: Quarried in the Lake Simcoe, Kingston, Ottawa, and Cornwall areas for crushed

stone. Rock from certain layers in eastern and central Ontario has proven to be alkali-reactive when used in Portland cement concrete (alkali-carbonate reaction). AGGREGATE SUITABILITY TESTING: PSV = 41-49, AAV = 8-12, $MgSO_4$ = 3-13, LA = 18-28, Absn = 0.3-0.9, BRD = 2.68-2.73, PN (Asphalt & Concrete) = 100-153.

Bobcaygeon Formation (Middle Ordovician)

STRATIGRAPHY: Part of the Simcoe Group (central Ontario) and the Ottawa Group (eastern Ontario), subdivided into upper, middle and lower members; members in eastern and central Ontario are approximately equivalent. COMPOSITION: homogeneous, massive to thin-bedded fine-crystalline limestone with numerous shaly partings in the middle member. THICKNESS: 80 to 285 feet (24 to 87 m). USES: Quarried at Brechin, Marysville, and in the Ottawa area for crushed stone. Generally suitable for use as granular base course aggregate. Rock from certain layers has been found to be alkali-reactive when used in Portland cement concrete (alkali-silica reaction). AGGREGATE SUITABILITY TESTING: PSV = 47-51, AAV = 14-23, $MgSO_4$ = 1-40, LA = 18-32, Absn = 0.3-2.4, BRD = 2.5-2.69, PN (Asphalt & Concrete) = 100-320.

Verulam Formation (Middle Ordovician)

STRATIGRAPHY: part of Simcoe and Ottawa Groups. COMPOSITION: fossiliferous, pure to argillaceous limestone interbedded with calcareous shale. THICKNESS: 105 to 230 feet (32 to 70 m). USES: Quarried at Picton and Bath for use in cement manufacture. Quarried for aggregate in Mara Township, Simcoe County and in the Belleville-Kingston area. May be unsuitable for use as aggregate in some areas because of its high shale content. AGGREGATE SUITABILITY TESTING: PSV = 43-44, AAV = 9-13, $MgSO_4$ = 4-45, LA = 22-29, Absn = 0.4-2.1, BRD = 2.59-2.70, PN (Asphalt & Concrete) = 120-255.

Lindsay Formation (Middle and Upper Ordovician)

STRATIGRAPHY: Part of Simcoe and Ottawa Groups; in eastern Ontario is divisible into an unnamed lower member and the Eastview Member; in central Ontario is divisible into the Collingwood Member (equivalent to portions of the Eastview Member) and a lower member. COMPOSITION: eastern Ontario - the lower member is interbedded, very fine- to coarse-crystalline limestone with undulating shale partings and interbeds of dark grey calcareous shale, whereas the Eastview Member is an interbedded dark grey to dark brown calcareous shale and very fine- to fine-crystalline, petroliferous limestone; central Ontario - Collingwood Member is a black, calcareous shale whereas the lower member is a very fine- to coarse-crystalline, thin-bedded limestone with very thin, undulating shale partings. THICKNESS: 82 to 200 feet (25 to 61 m). USES: eastern Ontario - lower member is used extensively for aggregate production; central Ontario - quarried at Picton, Ogden Point and Bowmanville for cement. May be suitable or unsuitable for use as concrete and asphalt aggregate. AGGREGATE SUITABILITY TESTING: $MgSO_4$ = 2-47, LA = 20-28, Absn = 0.4-1.3, BRD = 2.64-2.70, PN (Asphalt & Concrete) = 110-215.

Blue Mountain and Billings Formations (Upper Ordovician)

STRATIGRAPHY: central Ontario - Blue Mountain Formation includes the upper and middle members of the former Whitby Formation; eastern Ontario - Billings Formation is equivalent to part of the Blue Mountain Formation. COMPOSITION: Blue Mountain Formation - blue-grey, noncalcareous shales; Billings Formation - dark grey to black, noncalcareous to slightly calcareous, pyritiferous shale with dark grey limestone laminae and grey siltstone interbeds. THICKNESS: Blue Mountain Formation - 140 to 200 feet (43 to 61 m); Billings Formation - 0 to 205 feet (0 to 62 m). USES: Billings Formation may be a suitable source for structural clay products and expanded aggregate; Blue Mountain Formation may be suitable for structural clay products.

Georgian Bay and Carlsbad Formations (Upper Ordovician)

COMPOSITION: central Ontario - Georgian Bay Formation composed of interbedded limestone and shale; eastern Ontario - Carlsbad Formation composed of interbedded shale, siltstone and bioclastic limestone; THICKNESS: Georgian Bay Formation - 300 to 560 feet (91 to 170 m); Carlsbad Formation - 0 to 610 feet (0 to 186 m). USES: Georgian Bay Formation - used by several producers in Metropolitan Toronto area to produce brick and structural tile, as well as for making portland cement; at Streetsville, expanded shale was used in the past to produce lightweight aggregate. Carlsbad Formation - used as a source material for brick and tile manufacturing, has potential as a lightweight expanded aggregate.

Queenston Formation (Upper Ordovician)

COMPOSITION: Red, thin- to thick-bedded, sandy to argillaceous shale with green mottling and banding. THICKNESS: 400 to 500 feet (122 to 152 m). USES: There are several large quarries developed in the Queenston Formation in the Toronto-Hamilton region and one at Russell, near Ottawa. All extract shale for brick manufacturing. The Queenston Formation is the most important source material for brick manufacture in Ontario.

Whirlpool Formation (Lower Silurian)

STRATIGRAPHY: lower formation in the Cataract Group in the Niagara Penninsula and the Niagara Escarpment as far north as Duntroon. COMPOSITION: massive, medium- to coarse-grained, argillaceous white to light grey quartz sandstone with thin grey shale partings. THICKNESS: 0 to 25 feet (0 - 8 m). USES: building stone, flagstone.

Manitoulin Formation (Lower Silurian)

STRATIGRAPHY: part of the Cataract Group, occurs north of Stoney Creek. COMPOSITION: thin-bedded, blue-grey to buff-brown dolomitic limestones and dolostones. THICKNESS: 0 to 75 feet (0 to 23 m). USES: extracted for crushed stone in St. Vincent Township, Grey County, and for decorative stone on Manitoulin Island. AGGREGATE SUITABILITY TESTING: No data.

Cabot Head Formation (Lower Silurian)

STRATIGRAPHY: part of the Cataract Group, occurs throughout southern Ontario, south and north of the Niagara Escarpment. COMPOSITION: green, grey and red shales. THICKNESS: 50 to 60 feet (15 to 18 m); USES: potential source of coated lightweight aggregate and raw material for use in manufacture of brick and tile. Lack of suitability exposures has limited use.

Grimsby Formation

STRATIGRAPHY: upper formation of the Cataract Group, is identified on the Niagara Peninsula as far north as Clappison's Corners. COMPOSITION: interbedded sandstone and shale, mostly red. THICKNESS: 0 to 50 feet (0 to 15 m). USES: no present uses.

Thorold Formation (Middle Silurian)

STRATIGRAPHY: lower formation in the Clinton Group on the Niagara Peninsula. COMPOSITION: thick-bedded quartz sandstone. THICKNESS: 7 to 10 feet (2 - 3 m). USES: no present uses.

Neagha Formation (Middle Silurian)

STRATIGRAPHY: part of the Clinton Group on the Niagara Peninsula. COMPOSITION; dark-grey to green shale with minor interbedded limestone. THICKNESS: 0 to 5 feet (0 to 2 m). USES: no present uses.

Dyer Bay Formation (Middle Silurian)

STRATIGRAPHY: lower formation in the Clinton Group on Manitoulin Island and northernmost Bruce Peninsula. COMPOSITION: highly fossiliferous, impure dolostone. THICKNESS: 0 to 20 feet (0 to 6 m). USES: no present uses.

Wingfield Formation (Middle Silurian)

STRATIGRAPHY: part of the Clinton Group on Manitoulin Island and northernmost Bruce Peninsula. COMPOSITION: olive green to grey shale with dolostone interbeds. THICKNESS: 0 to 36 feet (0 to 11 m). USES: no present uses.

St. Edmund Formation (Middle Silurian)

STRATIGRAPHY: part of the Clinton Group on Manitoulin Island and northernmost Bruce Peninsula, upper portion previously termed the Mindemoya Formation. COMPOSITION: pale grey to buff-brown, micro- to medium-crystalline, thin- to medium-bedded dolostone. THICKNESS: 0 to 85 feet (0 to 26 m). USES: quarried for fill and crushed stone on Manitoulin Island. AGGREGATE SUITABILITY TESTING: $MgSO_4$ = 1-2, LA = 19-21, Absn = 0.6-0.7, BRD = 2.78-2.79, PN (Asphalt & Concrete) = 105.

Fossil Hill and Reynales Formations (Middle Silurian)

STRATIGRAPHY: part of Clinton Group; Fossil Hill Formation occurs in the northern part of the Niagara Escarpment and is approximately equivalent in part to the Reynales Formation which occurs on the Niagara Peninsula and the Escarpment as far north as the Forks of the Credit. COMPOSITION: Fossil Hill Formation - fine- to coarse-crystalline dolostone with high silica content; Reynales Formation - thin- to thick-bedded shaly dolostone and dolomitic limestone. THICKNESS: Fossil Hill Formation - 20 to 85 feet (6 to 26 m); Reynales Formation - 0 to 10 feet (0 to 3 m). USES: both formations quarried for aggregate with overlying Amabel and Lockport Formations. AGGREGATE SUITABILITY TESTING: (Fossil Hill Formation on Manitoulin Island) $MgSO_4$ = 41, LA = 29, Absn = 4.1, BRD = 2.45, PN (Asphalt & Concrete) = 370.

Irondequoit Formation (Middle Silurian)

STRATIGRAPHY: part of Clinton Group on the Niagara Peninsula south of Waterdown. COMPOSITION: massive, coarse-crystalline crinoidal limestone. THICKNESS: 0 to 7 feet (0 to 2 m). USES: not significantly utilized.

Rochester Formation (Middle Silurian)

STRATIGRAPHY: part of Clinton Group along the Niagara Peninsula. COMPOSITION: black to dark grey calcareous shale with numerous limestone lenses. THICKNESS: 15-60 feet (5-18 m). USES: not significantly utilized. AGGREGATE SUITABILITY TESTING: PSV = 69, AAV = 17, $MgSO_4$ = 95, LA = 19, Asbn = 2.2, BRD = 2.67, PN (Asphalt & Concrete) = 400.

Decew Formation (Middle Silurian)

STRATIGRAPHY: part of Clinton Group south of Waterdown along the Niagara Peninsula. COMPOSITION: sandy to shaly dolomitic limestone and dolostone. THICKNESS: 0 to 15 feet (0 to 5 m). USES: too shaly for high quality uses, but is quarried along with Lockport Formation in places. AGGREGATE SUITABILITY TESTING: PSV = 67, AAV = 15, $MgSO_4$ = 55, LA = 21, Absn = 2.2, BRD = 2.66, PN (Asphalt & Concrete) = 255.

Lockport and Amabel Formations (Middle Silurian)

STRATIGRAPHY: Lockport Formation occurs from Waterdown to Niagara Falls, subdivided into 3 formal members: Gasport, Goat Island and Eramosa Members and an informal member (the "Vinemount shale beds"); the stratigraphically equivalent Amabel Formation, found from Waterdown to Cockburn Island, is subdivided into Lions Head, Wiarton/Colpoy Bay, and Eramosa Members. COMPOSITION: Lockport Formation is thin- to massive-bedded, fine- to medium-crystalline dolostone; Amabel Formation is thin bedded to massive, medium-crystalline dolostone with reef facies near Georgetown and on the Bruce Peninsula. THICKNESS: (Lockport/ Amabel) 10 to 130 feet (3 to 40 m). USES: both formations have been used to produce lime, crushed stone, concrete aggregate, and building stone throughout their area of occurrence, and are a resource of provincial significance. AGGREGATE SUITABILITY TESTING: PSV = 36-49, AAV = 10-17, $MgSO_4$ = 2-6, LA = 25-32, Absn = 0.4-1.54, BRD = 2.61-2.81, PN (Asphalt & Concrete) = 100-105.

Guelph Formation (Middle Silurian)

STRATIGRAPHY: Exposed on the Niagara Escarpment from the Niagara River to the tip of the Bruce Peninsula, mostly present in the subsurface of southwestern Ontario. COMPOSITION: Micro-crystalline to medium-crystalline, thick-bedded, soft, porous dolostone, characterized in places by extensive vuggy, porous reefal facies of high chemical purity. THICKNESS: 100 to 170 feet (30 to 52 m). USES: Some areas appear soft and unsuitable for use in the production of load-bearing aggregate. This unit requires additional testing to fully establish its aggregate suitability. Main use is for dolomitic lime for cement manufacture. Quarried near Hamilton and Guelph.

Salina Formation (Upper Silurian)

STRATIGRAPHY: present in the subsurface of southwestern Ontario; only rarely exposed at the surface. COMPOSITION: grey and maroon shale, brown dolostone and, in places, salt, anhydrite and gypsum; consists predominantly of evaporitic rich material with up to eight units identifiable. THICKNESS: 370 to 600 feet (113 to 183 m). USES: Gypsum mines at Hagersville, Caledonia, and Drumbo. Salt is mined at Goderich and Windsor and is produced from brine wells at Amherstburg, Windsor and Sarnia.

Bertie and Bass Islands Formations (Upper Silurian)

STRATIGRAPHY: Bertie Formation found in southern Niagara Peninsula; Bass Islands Formation, the Michigan Basin equivalent of the Bertie Formation, does not significantly outcrop in Ontario but is present in the subsurface in southwestern Ontario; Bertie Formation represented by Oatka, Falkirk, Scajaquanda, Williamsville, and Akron Members. COMPOSITION: medium- to massive-bedded, micro-crystalline, brown dolostone with shaly partings. THICKNESS: 45 to 160 feet (14 to 49 m). USES: Quarried for crushed stone on the Niagara Peninsula at Fort Erie, Cayuga, Hagersville and Dunnville; shaly intervals are unsuitable for use as high specification aggregate because of low freeze-thaw durability. Has also been extracted for lime. AGGREGATE SUITABILITY TESTING: PSV = 46-49, AAV = 8-11, $MgSO_4$ = 4-19, LA = 14-23, Absn = 0.8-2.8, BRD = 2.61-2.78, PN (Asphalt & Concrete) = 102-120.

Oriskany Formation (Lower Devonian)

STRATIGRAPHY: basal Devonian clastic unit, found in Niagara Peninsula. COMPOSITION: thick-to massive-bedded, coarse-grained, grey-yellow sandstone. THICKNESS: 0 to 15 feet (0 to 5 m). USES: Has been quarried for silica sand, building stone, and armour stone. May be acceptable for use as rip rap, and well cemented varieties may be acceptable for some asphaltic products. AGGREGATE SUITABILITY TESTING: (of a well cemented variety of the formation) PSV = 64, AAV = 6, $MgSO_4$ = 2, LA = 29, Absn = 1.2-1.3, BRD = 2.55, PN (Asphalt & Concrete) = 107.

Bois Blanc Formation (Lower Devonian)

STRATIGRAPHY: Springvale Sandstone Member forms the lower portion of formation. COMPOSITION: a cherty limestone with shale partings and minor interbedded dolostones; Springvale Sandstone Member is a medium- to coarse-grained, green glauconitic sandstone with interbeds of limestone, dolostone and brown chert. THICKNESS: 10 to 130 feet (3 to 40 m). USES: Quarried at Hagersville, Cayuga, and Port Colborne for crushed stone. Material generally unsuitable for concrete aggregate because of high chert content. AGGREGATE SUITABILITY TESTING: PSV = 48-53, AAV = 3-7, $MgSO_4$ = 3-18, LA = 15-22, Absn = 1.3-2.8, BRD = 2.50-2.70, PN (Asphalt & Concrete) = 102-290.

Onondaga Formation (Middle Devonian)

STRATIGRAPHY: correlated to part of the Detroit River Group; occurs on the Niagara Peninsula from Simcoe to Niagara Falls; contains the Edgecliff, Clarence, and Moorehouse Members. COMPOSITION: medium-bedded, fine- to coarse-grained, dark grey-brown or purplish-brown, variably cherty limestone. THICKNESS: 60 to 82 feet (18 to 25 m) USES: Quarried for crushed stone on the Niagara Peninsula at Welland and Port Colborne. High chert content makes much of the material unsuitable for use as concrete aggregate and asphaltic concrete. Has been used as a raw material in cement manufacture. AGGREGATE SUITABILITY TESTING: (Clarence and Edgecliff Members) $MgSO_4$ = 1-6, LA = 16.8-22.4, Absn = 0.5-1.1, PN (Asphalt & Concrete) = 190-276.

Amherstburg Formation (Middle Devonian)

STRATIGRAPHY: part of Detroit River Group; correlated to Onondaga Formation in Niagara Penninsula; contains Sylvania Sandstone Member and Formosa Reef Limestone. COMPOSITION: bituminous, bioclastic, stromatoporoid-rich limestone with grey chert nodules; Formosa Reef Limestone - high purity (calcium rich) limestone; Sylvania Sandstone Member - quartz sandstone. THICKNESS: 0 to 165 feet (0 to 50 m); Formosa Reef Limestone - up to 85 feet (26 m). USES: cement manufacture, agricultural lime, aggregate. AGGREGATE SUITABILITY TESTING: PSV = 57, AAV = 19, $MgSO_4$ = 9-35, LA = 26-52, Absn = 1.1-6.4, BRD = 2.35-2.62, PN (Asphalt & Concrete) = 105-300.

Lucas Formation (Middle Devonian)

STRATIGRAPHY: part of the Detroit River Group in southwestern Ontario; includes the Anderdon Member which, in the Woodstock Beachville area, may constitute the bulk of the formation. COMPOSITION: light brown or grey-brown dolostone with bituminus laminations and minor chert; Anderdon Member consists of very high purity (calcium-rich) limestone. THICKNESS: 130 to 246 feet (40 to 75 m). USES: Most important source of high-purity limestone in Ontario. Used as calcium lime for metallurgical flux and for the manufacture of chemicals. Rock of lower purity is used for cement manufacture, agricultural lime and aggregate. Anderdon Member is quarried at Amherstburg for crushed stone. AGGREGATE SUITABILITY TESTING: PSV = 46-47, AAV = 15-16, $MgSO_4$ = 2-60, LA = 22-47, Absn = 1.1-6.5, BRD = 2.35-2.40, PN (Asphalt & Concrete) = 110-160.

Dundee Formation (Middle Devonian)

STRATIGRAPHY: few natural outcrops, largely in the subsurface of southwestern Ontario. COMPOSITION: Fine- to medium-crystalline, brownish-grey, medium- to thick-bedded, dolomitic limestone with shaly partings sandy layers, and chert in some areas. THICKNESS: 50 to 100 feet (15 to 30 m). USES: Quarried near Port Dover and on Pelee Island for crushed stone. Used at St. Marys as a raw material for portland cement. AGGREGATE SUITABILITY TESTING: $MgSO_4$ = 1-28, LA = 22-46, Absn = 0.6-6.8, PN (Asphalt & Concrete) = 125-320.

Marcellus Formation (Middle Devonian)

STRATIGRAPHY: subsurface unit, mostly found below Lake Erie and extending into the eastern U.S.A., pinches out in the Port Stanley area. COMPOSITION: black, bituminous shales. THICKNESS: 0 to 15 feet (0 to 5 m). USES: no present uses.

Bell Formation (Middle Devonian)

STRATIGRAPHY: lowest formation of the Hamilton Group, no out-crop in Ontario. COMPOSITION: soft blue and grey calcareous shale. THICKNESS: 0 to 30 feet (0 to 9 m). USES: no present uses.

Rockport Quarry Formation (Middle Devonian)

STRATIGRAPHY: part of the Hamilton Group; no outcrop in Ontario. COMPOSITION: grey-brown, very fine-grained limestone with occasional shale layers. THICKNESS: 0 to 20 feet (0 to 6 m). USES: no present uses.

Arkona Formation (Middle Devonian)

STRATIGRAPHY: Part of the Hamilton Group. COMPOSITION: blue-grey, plastic, clay shale with occasional thin and laterally discontinuous limestone lenses. THICKNESS: 15 to 120 feet (5 to 37 m). USES: has been extracted at Thedford and near Arkona for the production of drainage tile.

Hungry Hollow Formation (Middle Devonian)

STRATIGRAPHY: part of the Hamilton Group. COMPOSITION: grey crinoidal limestone and soft, fossiliferous calcareous shale. THICKNESS: 0 to 6 feet (0 to 2 m). USES: suitable for some crushed stone and fill with selective quarrying. AGGREGATE SUITABILITY TESTING: No data.

Widder Formation (Middle Devonian)

STRATIGRAPHY: part of the Hamilton Group. COMPOSITION: mainly soft, grey, fossiliferous calcareous shale interbedded with blue-grey, fine-grained fossiliferous limestone. THICKNESS: 0 to 45 feet (0 to 14 m). USES: no present uses.

Ipperwash Formation (Middle Devonian)

STRATIGRAPHY: upper formation of the Hamilton Group; very limited distribution. COMPOSITION: medium- to coarse grained, grey-brown, bioclastic limestone. THICKNESS: 5 to 45 feet (2-14 m). USES: no present uses.

Kettle Point Formation (Upper Devonian)

STRATIGRAPHY: occurs in a band between Sarnia and Erieau; small part overlain by Port Lambton Group rocks in extreme northwest. COMPOSITION: black, highly fissile, organic-rich shale with minor interbeds of grey-green silty shale. THICKNESS: 0 to 200 feet (0 to 61 m). USES: possible source of fill; possible source of material for use as sintered lightweight aggregate.

Bedford Formation (Upper Devonian)

STRATIGRAPHY: lower formation of the Port Lambton Group. COMPOSITION: soft, grey shale. THICKNESS: 0 to 108 feet (0 to 33 m). USES: no present uses.

Berea Formation (Upper Devonian)

STRATIGRAPHY: middle formation of the Port Lambton Group; not known to occur at surface in Ontario. COMPOSITION: grey, fine to medium grained sandstone, often dolomitic and interbedded with grey shale and siltstone. THICKNESS: 0 to 197 feet (0 to 60 m). USES: no present uses.

Sunbury Formation (Upper Devonian)

STRATIGRAPHY: upper formation of the Port Lambton Group; not known to occur at surface in Ontario. COMPOSITION: black shale. THICKNESS: 0 to 66 feet (0 to 20 m). USES: no present uses.

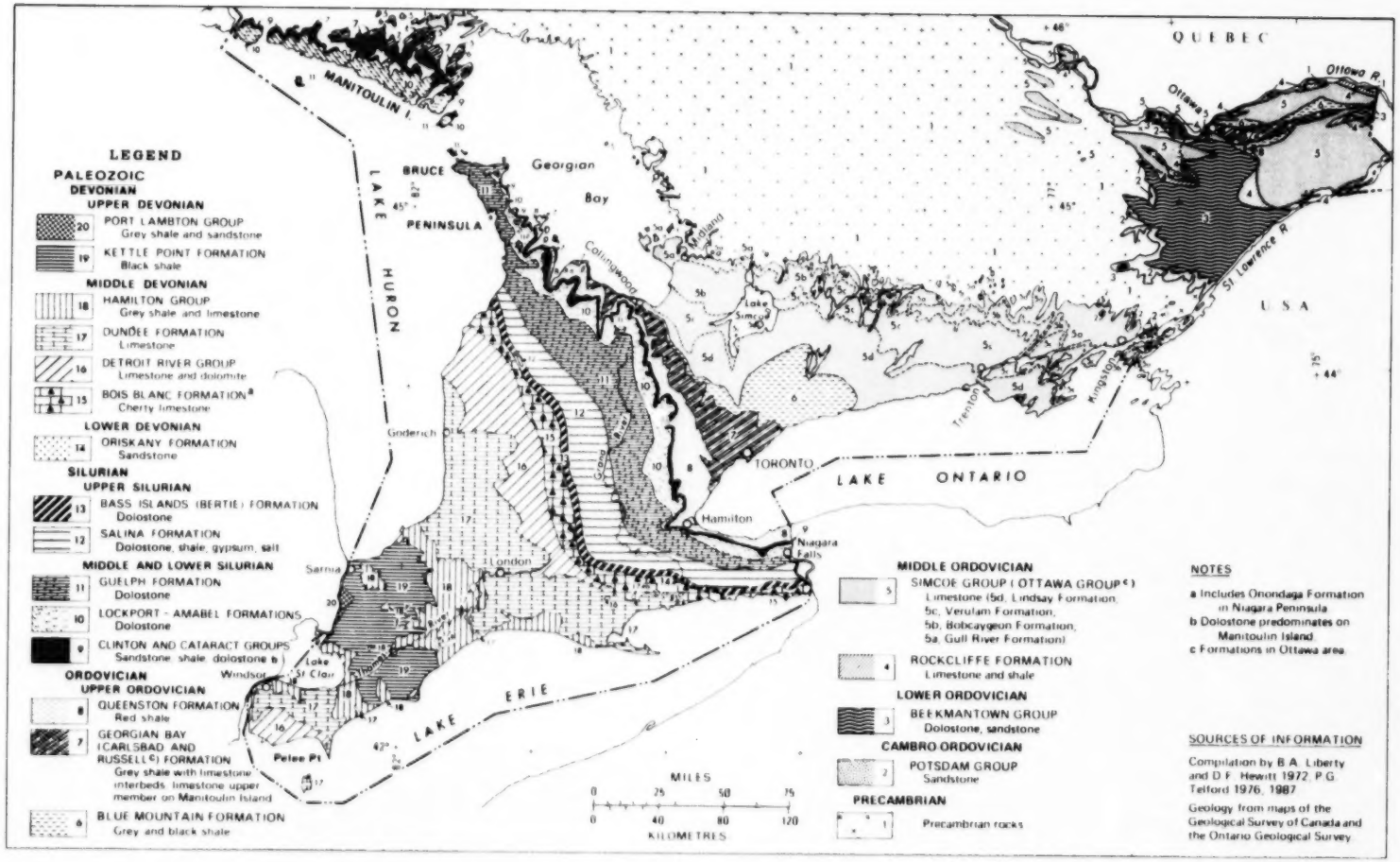

Figure 6. *Bedrock Geology of Southern Ontario.*

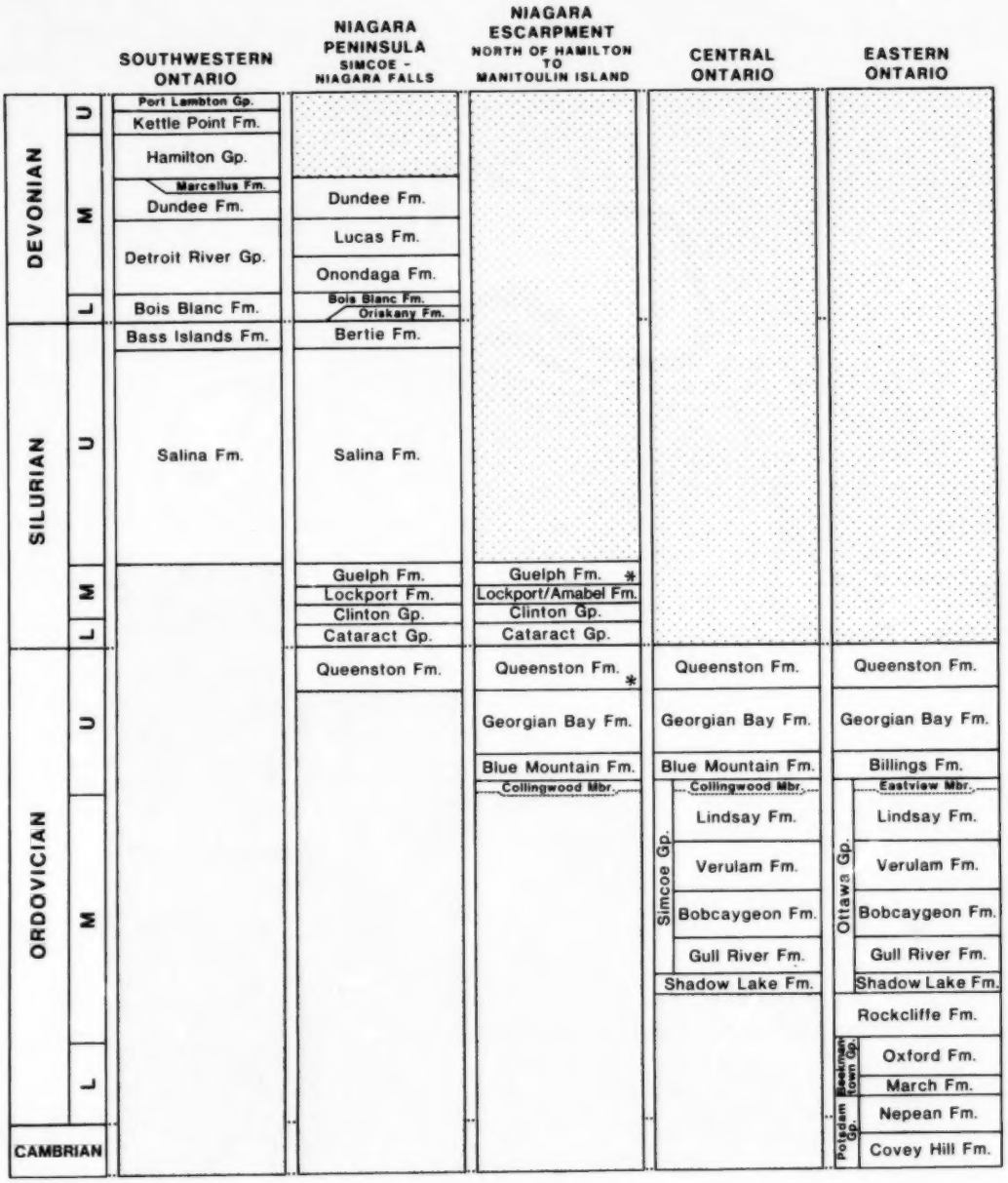

Figure 7. *Exposed Paleozoic Stratigraphic Sequences in Southern Ontario (adapted from: Bezys, R.K., and Johnson, M.D. In Press: The Geology of Paleozoic Formations Utilized by the Limestone Industry of Ontario; The Canadian Mining and Metallurgical Bulletin).*

Appendix E — Aggregate Quality Test Specifications

Four types of aggregate quality tests are often performed by the Ontario Ministry of Transportation on sampled material. A description of each test is found in Appendix B and the specification limits for each test are given in this appendix. Although a specific sample meets or does not meet the specification limits for a certain product, it may or may not be acceptable for that use based on field performance. Additional quality tests other than the four major tests listed in this appendix can be used to determine the suitability of an aggregate. The tests are performed by the Soils and Aggregates Section, Engineering Materials Office, Ontario Ministry of Transportation.

TABLE 11. SELECTED QUALITY REQUIREMENTS FOR MAJOR AGGREGATE PRODUCTS.

	TYPE OF TEST				
	COARSE AGGREGATE				FINE AGGREGATE
TYPE OF MATERIAL	Petrographic Number Maximum	Magnesium Sulphate Soundness - Max. % Loss	Absorption Maximum %	Los Angeles Abrasion Maximum % Loss	Magnesium Sulphate Soundness Maximum % Loss
Granular Base A	200	-	-	60	-
16 mm Crushed Type 'A'	160	-	-	35	-
16 mm Crushed Type 'B'	200	-	-	60	-
Granular Subbase B	250	-	-	-	-
Granular Subbase C	250	-	-	-	-
Granular Subbase D	-	-	-	-	-
Hot Mix - H. L. 1	100	5	1.0	15	16
Hot Mix - H. L. 2	-	-	-	-	20
Hot Mix - H. L. 3	135	12	1.75	35	16
Hot Mix - H. L. 4	160	12	2.0	35	20
Hot Mix - H. L. 8	160	15	2.0	35	20
Structural Concrete and Concrete Base	140	12	2.0	35	16
Pavement Concrete and Exposed Structure Deck	125	12	2.0	35	16

(Ministry of Transportation Forms 1002, 1003 and 1010)

MAPS
NOT
FILMED

CARTES
OMISES